GUIDE BOOK No. 1

W. J. Lamuré

EXCURSION

IN

Eastern Quebec and the Maritime Provinces

(EXCURSION A 1.)

PART I

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
GOVERNMENT PRINTING BUREAU
1913

35063—1

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(G. A. Young.)

The part of Canada lying east of the St. Lawrence river below Quebec city and having a width of about 500 miles (800 km.) in an east and west direction, includes the provinces of Nova Scotia, Prince Edward Island, and New Brunswick, and a part of the province of Quebec. Though presenting a great diversity of physical and geological features, the region as a whole may be regarded as a unit inasmuch as the geological and physical provinces into which the region is divisible, all trend in a northeasterly direction. Having regard, then, to the structural elements, the region may be said to have a width of 375 miles (595 km.) measured from the St. Lawrence on the northwest, to the Atlantic coast of Nova Scotia on the southeast.

One of the more marked physical provinces of the region is the plain bordering the St. Lawrence—the St. Lawrence lowland. A very marked feature to the southwest of Quebec city, this plain to the northeast gradually narrows and is limited to the territory immediately bordering the St. Lawrence on the south. To the southeast, the St. Lawrence lowland merges into an elevated tract of country extending in a general northeasterly direction. Southwest of the latitude of Quebec city, this upland is formed, in Canada, by three rudely parallel ridges which over considerable areas rise above 2,000 feet (600 m.). Proceeding northeastward to a point east of the city of Quebec, this upland, the Notre Dame mountains, sinks to lower and lower elevations, but beyond, to the northeast, it again increases in height, so that in Gaspe peninsula it forms an uplifted area with a general elevation of from 1,000 to 2,000 feet (300 to 600 m.) with peaks rising above 3,500 feet (1,050 m.).

The higher more rugged portion of this upland is bordered on the southwest, in the Gaspe Peninsula, by a plateau-like region extending to the shores of the Bay of Chaleur, and having a general elevation of about 1,000 feet (300 m.). This plateau-like upland extends in a southwest direction through northwestern New Brunswick and continues southward on both sides of the St. John valley where the

general elevation is however, considerably less than 1,000 feet (300 m.).

In New Brunswick, the plateau area is bordered on the southwest by a much more rugged area with numerous peaks rising above 2,000 feet (600 m.). This broken, semi-mountainous tract occupies the central portion of the province. It is bounded on the southwest by a lowland area of about 10,000 square miles (26,000 sq. km.) over which the general elevation is less than 500 feet (150 m.). This lowland reaches on the east, to the Gulf of St. Lawrence, forms the whole of Prince Edward Island, and extends easterly into Nova Scotia along the north side of the Cobequid hills. In New Brunswick, the lowland is bordered on the south by Caledonia mountain, a wide ridge rising steeply from the northwestern shores of the Bay of Fundy and having over a considerable area, a general altitude of about 1,200 feet (360 m.). In Nova Scotia, the upland area of the Cobequid hills forms the southern boundary of the extensive lowland. The Cobequid hills run in an easterly direction from the head of the Bay of Fundy. They have a general elevation in the neighbourhood of 600 to 900 feet (180 to 270 m), and on their south side slope down to Minas Basin, an easterly prolongation of the Bay of Fundy.

The peninsula of Nova Scotia is formed mainly of an upland area extending in a general northeasterly direction and having along its axial line a general elevation of about 1,000 feet (300 m.). On the southeastern side it falls gradually to the ocean, on the northwestern side its slopes are steeper and it is in part, bounded by a lowland area surrounding the Cobequid hills and extending westward into New Brunswick. The island of Cape Breton forms the northeastern extension of the main upland of Nova Scotia, and on this island the upland area, though broken into isolated ridges, attains a maximum altitude of above 1,500 feet (450 m.).

The wide channel of the St. Lawrence on the northwest forms the natural boundary of the region in this direction. To the northwest of the river valley stretches the vast Pre-Cambrian area of the "Canadian Shield" which abruptly rises from the St. Lawrence shores to heights of 1,000 feet (300 m.) and more. At widely separated intervals along the northwest shore, and on Anticosti island and on some of the smaller islands, are displayed

nearly horizontal or gently dipping strata ranging in age from lower Ordovician to uppermost Silurian. The measures rest on the Pre-Cambrian and abut against the edge of the upland area of the Canadian Shield.

Along the southwestern shore of the St. Lawrence, the strata, striking in a northeasterly direction, are closely folded, in a large measure overturned, and are traversed by many dislocations, along some of which the strata from the southeast are thrust over the beds to the northwest. In age these measures range from late Ordovician to Cambrian; they belong to the Quebec group and differ lithologically and faunally from the nearly horizontal strata of the islands and north shore of the St. Lawrence and from which they are separated by a great fault or zone of faulting that strikes in a southeasterly direction beneath the waters of the St. Lawrence as far as the neighbourhood of Quebec city and from there, continuing with the same general direction, runs through the land area to Lake Champlain and beyond.

The band of the Quebec group which borders the St. Lawrence below Quebec, varies in width from 6 miles to 35 miles (9.6 to 56 km.). On the southeast these rocks are bounded by a great area of strata that in the main, range in age from Devonian to Silurian. Such measures form the greater part of the peninsula of Gaspe and, stretching to the southwest from the upper part of Chaleur bay, occupy the northwestern portion of New Brunswick. Along their northwestern boundary, these measures in places overlap the Quebec group strata, in other places have been thrust over them, while along the mountainous axes of the Gaspe peninsula a narrow zone of Palæozoic igneous rocks and deformed strata possibly of Pre-Cambrian age, intervenes.

The strata of this essentially Silurian and Devonian area, are folded along axial lines which, in the southwest, strike to the northeast but which in the Gaspe peninsula swing to an easterly course. In certain districts, the strata lie in open folds, but perhaps over the greater part of the region the folding is closer and in many places the beds are crumpled and highly faulted.

In Gaspe, the Silurian and Devonian measures occupy an area having a breadth of 70 miles (110 km); to the southwest, in New Brunswick, the area is approximately 150 miles (240 km.) wide. In the southeastern part of

this region, in New Brunswick, Ordovician strata are also present, and associated with the sedimentary beds are extrusive and intrusive volcanic rocks and batholitic bodies of Devonian granite. By far the greater part of the region, however, is underlain by marine sediments representing nearly the whole of the Silurian and the lower part of the Devonian systems. In the Gaspe peninsula, are large areas of higher Devonian strata, rich in plant remains.

As already mentioned, the southeastern portion of the above described region is characterized in New Brunswick, by the presence with the Silurian and Devonian, of Ordovician strata and of volcanic rocks and large bodies of granite. This bordering zone stretches southwestward through New Brunswick from Chaleur bay to the Maine boundary, a distance of 175 miles (281 km.), and has an average breadth of about 40 miles (65 km.). In the extreme southwest, this complex projects eastward to the Atlantic coast and there has a total width of about 90 miles (145 km.). Presumably this zone of Silurian and older strata and the associated volcanic and plutonic rocks with a breadth of not much less than 100 miles (160 km.), extends to the northeast to the Gulf of the St. Lawrence, but to the northeast not far from the Maine boundary, these rocks, in part disappear beneath a mantle of Carboniferous measures occupying a triangular stretch of low-lying country having an area of about 10,000 square miles (26,000 sq. k.m.).

The Carboniferous strata of this extensive area, are mainly of Millstone Grit (mid-Carboniferous) age. Except locally along the southern margin, the strata are flat-lying, almost undisturbed. The rocks consist chiefly of sandstones and shales with relatively thin beds of coal. Along the southern margin of the Carboniferous area, older divisions of the Carboniferous are present and locally are much folded and faulted. This area of undisturbed measures is represented to the east on Prince Edward Island and on the Nova Scotia mainland facing Prince Edward Island, but in this eastern district, the essentially undisturbed measures are of late Carboniferous and early Permian age.

The great triangular area of Carboniferous rocks in New Brunswick, is limited, as already stated, on the northwest and on the extreme west and south, by Silurian and older strata associated with and penetrated by volcanic

and plutonic rocks. But along the eastern half of the southern border of the Carboniferous area, the Carboniferous rocks abut against and extend into an area dominantly occupied by Pre-Cambrian rocks with which are associated Cambrian and perhaps younger Palæozhic sediments. This complex forms another of the northeasterly extending zones which so characterize the general region. This area, essentially underlain by Pre-Cambrian rocks, borders the Bay of Fundy coast which apparently truncates the Pre-Cambrian area. In places, along the Bay of Fundy coast, the Pre-Cambrian zone is fringed with Carboniferous strata and it may be that the Bay of Fundy trough has been developed chiefly in Carboniferous and younger measures.

The province of Nova Scotia lies southeast of New Brunswick and is almost completely severed from it by the Bay of Fundy. The peninsula of Nova Scotia, including the mainland and the continuing area of Cape Breton Island to the northeast, has a length, along a nearly due northeast course, of about 360 miles (580 km.) and an average breadth of about 60 miles (95 km.). In this province the main geological structures are less broadly and more irregularly developed than in the region to the northwest and therefore may not be so readily outlined in generalized terms.

The southwestern portion of the peninsula of Nova Scotia is almost entirely occupied by a broadly folded sedimentary series of late Pre-Cambrian age penetrated by large batholiths of granite of Devonian age. These rocks extend to the northeast with a gradually diminishing width, and outcrop along the whole length—270 miles (435 km.)— of the Atlantic coast of the Nova Scotian peninsula. In the southwest these measures are bordered on the northwest for a distance of about 120 miles (190 km.) by small detached areas of late Silurian and early Devonian strata which in their turn are bordered by a narrow strip of Triassic strata forming the Bay of Fundy shore. To the northeast, however, the Pre-Cambrian sediments and their intrusive granites are bordered by Carboniferous strata which, encircling large and small areas of older Palæozoic sediments and igneous rocks, extend westward to join the Carboniferous area of New Brunswick. The island of Cape Breton, to the northeast, is in the main underlain by ancient Pre-Cambrian strata occupying

large and small, detached areas which are surrounded and penetrated by Carboniferous measures.

PHYSIOGRAPHY.

(J. W. Goldthwait.)

Eastern Quebec and the Maritime Provinces lie at the northeastern end of the Appalachian Mountain region of eastern United States and Canada. This region, although not generally mountainous at the present time, possesses a complex and crumpled rock structure which can only have been produced by diastrophism. Since Cambrian, Ordovician, Silurian, and Devonian sediments are all involved in the close folds, and partake of the regional metamorphism that characterizes the province, it is evident that the region was very mountainous in Palæozoic time. While the Mesozoic rocks have suffered much less deformation, they too, show that as late as the end of the Jurassic period diastrophism was taking place on a large scale. It is probable then, that at the beginning of the Cretaceous period this whole region was occupied by lofty mountain chains. During the closing part of the Mesozoic, however, subaerial denudation appears to have held sway without interruption from diastrophism. The mountains were slowly but surely reduced to a plain of low relief, or "peneplain". Remnants of this great baselevelled surface of the Cretaceous can be found along the Appalachian system all the way from New Brunswick to Alabama. Locally, in districts remote from the coast, and where stronger rock structures appeared just above the Cretaceous base-level, the reduction of the surface was incomplete, and many residual mountains or "monadnocks" were left. On the whole, however, the baselevelling was very thorough, planing away the harder rocks as well as the weaker.

This almost complete cycle of denudation was brought to a close at about the beginning of the Tertiary by regional uplifts of continental extent. All along the Appalachian province, in United States and Canada, the Cretaceous peneplain was raised, with more or less warping converting the lowland into an upland. The uplift seems everywhere to have been greatest in the interior and least near the coast. By it, the seaward flowing rivers were revived,

and a new cycle of erosion was begun. Where the upland possessed weak rock structures, as in the Carboniferous areas of eastern New Brunswick and the Triassic areas of Nova Scotia and southern New England, the new denudation progressed rapidly, and by mid-Tertiary time broad lowlands had been developed. Meanwhile, wherever weather-resisting rocks predominated, gorges and narrow valleys were cut, dissecting the upland into a rolling hilly country. By the time this second cycle of denudation had been nearly completed in the lowlands, another elevation of the region occurred, attended like the first, by local warping. The lowlands were again carved by streams until a fairly mature topography had been evolved beneath the Tertiary surface.

All this occurred before the Glacial period. With the development of an ice sheet over all northern North America, at the beginning of the Pleistocene, a series of events took place, whose exact nature and sequence, so far as the Maritime Provinces are concerned, are still largely problematical. Most of the region in question was sooner or later covered by the continental ice, and given a new coat of mantle rock or "drift." Portions of the Gaspe peninsula and Nova Scotia may have remained outside the limits of glaciation. No one can say positively, as yet, whether the ice which spread over this region came from the centre east of Hudson bay, or whether there were two or more separate centres of dispersal of the continental glacier within the limits of the Maritime Provinces. From evidence gathered during twenty years of field work, the late Dr. Robert Chalmers came to believe that the more easterly portions of the region, at least, were glaciated solely by ice from the interior of New Brunswick and the Gaspe peninsula, while southern Quebec, only, was reached by ice from the Hudson bay region.

There is much uncertainty, also, about changes of level in land and sea during the Pleistocene. Whatever elevations or subsidences may have gone on in the earlier epochs, it is plain that when the ice sheet finally withdrew from the south coast of the lower St. Lawrence and the Champlain valley, the land stood several hundred feet lower than now. The coast of New England and New Brunswick, likewise, was deeply submerged. The elevation of these coasts to their present position appears to have

commenced as soon as the ice sheet withdrew and to have proceeded steadily and rapidly By this uplift ancient wave built beaches and marine clays containing fossils of characteristic Arctic shellfish, have been raised to altitudes of from 50 to 600 feet (15 to 180 m.) above sea level. Although differential, the movement was remarkably uniform, without any local buckling or dislocation of the geoid surface. Even with this recently acquired altitude, the coast stands lower to-day than it did at the beginning of the Pleistocene; for the larger valleys, the St. Lawrence, Restigouche, and Miramichi, are estuaries, still deeply drowned beneath the sea. More recently there have been minor changes of level along the coast. On the St. Lawrence east of Quebec, through a distance of 400 miles (640 km.), an elevation of 20 feet (6 m.) has occurred, in which there is no sign of warping. This uplift has laid bare a narrow marine shelf, overlooked by an old sea cliff—the most remarkable record of wave work in the province. Around the head of the Bay of Fundy, on the other hand, tree stumps buried deeply beneath the salt marsh deposits, indicate a recent subsidence of the coast. No satisfactory correlation of these data has yet been reached. At present although the coast generally is being rapidly cut away by the sea, it seems to be neither rising nor sinking.

Upland of northwestern New Brunswick.—From the head of Chaleur bay and the Gaspe peninsula southwestward, a wide belt of upland country stretches across the northwest corner of New Brunswick into Maine. In structure it is a part of the great Appalachian upland of northern New England. Its rocks are mainly calcareous slates and limestones of Silurian age. During one of the periods of long continued denudation, perhaps in the Tertiary, this district and the adjoining territory in Quebec was reduced to a lowland, while the district just east of it, the Central Highland of New Brunswick, remained standing because of its harder rock structure. The plateau-like altitude of the upland as we see it to-day was gained subsequently, when the peneplain, together with the adjoining highland was raised several hundred feet. Since then it has been very extensively dissected by streams. The hilltops of this upland range from 800 to 1,000 feet (240 to 300 m.) above the sea. A few residual mountains, as, for instance, Mars hill in Maine, five

miles west of Upper Kent station, rise several hundred feet above the peneplain.

Records of the Glacial period, as yet not extensively studied in this district, indicate that the continental ice passed southward and southeastward across it—whether from a centre north of the St. Lawrence or from a local centre on the Appalachian highland of southeastern Quebec cannot now be stated. During the closing stages of glaciation, the larger valleys, notably that of the St. John river, were heavily aggraded with outwash deposits, which ceased to accumulate as soon as the ice sheet had withdrawn from their basins, and have since been deeply re-excavated by the rivers which occupy them. In this work of intrenchment, the rivers have swung too and fro within limits set by the bed rock slopes on either hand, repeatedly striking ledges, from which they have retired, leaving step-like flights of terraces.

The Central Highland of New Brunswick.—Just east of the district last described, and occupying a large area in the north central part of New Brunswick, is a vast rough wilderness known as the Central highland. Its greater relief is due to the superior strength of the granites and gneisses which appear extensively on its surface. There is a rough accordance of plateau-like remnants at 1,700 feet (515 m.), which are overlooked by summits of rather subdued form that rise as high as 2,500 feet (760 m.). The hills and ridges trend northeast-southwest, following the trend of rock structure. Around the border of this highland is a belt of foot hills and ridges of moderate relief, developed on hard sandstones and slates. Apparently the highland is an imperfectly reduced portion of the great Cretaceous peneplain of New England, which, like the higher parts of the White mountains of New Hampshire and Mt. Ktaadn in Maine, retain subdued mountain form.

Lowlands of eastern New Brunswick and northwestern Nova Scotia.—The Carboniferous lowland of eastern New Brunswick in its structure and history, is simply an extension of the Cumberland lowland of Nova Scotia. Its area, however, is very much greater than that of the other, and its relief, in the more remote interior is stronger. Between Newcastle and Bathurst the highest point reached by the railway is Bartibog station, 520 feet (158·5 m.). In this district the valleys are deep and narrow, with banks

kept steep by lateral planation. The upland is noticeably uniform in height. West and southwest of Bathurst on the other hand, where stronger Ordovician and Silurian strata and large stocks of granite come to the surface, the upland is higher and rougher. The Tertiary peneplain *par excellence* is found along the coast of Gloucester county east of Bathurst. There the upland is exceedingly smooth and ow. The valleys which thoroughly indent it are broad and shallow, turning and twisting in graceful curves, and branching repeatedly in all directions. The dissection of this part of the peneplain is fully mature. Drowning appears to have taken place eaily in the Pleistocene; at least, it is clear that before the close of the Ice Age, while the interior of the province was still covered by the ice sheet, these valleys were more deeply submerged than now. Below the 150-foot (45 m.) level the coast is very generally covered with a sheet of residual sands overlying the decayed sandstones. Upon this loose material rests a few inches of wave-washed sediment and a scattering of subangular till pebbles and striated boulders. Clearly, the weathered surface of the peneplain here has escaped erosion from the continental ice sheet by remaining under water while pack ice or bergs, drifting along the shore, dropped glacial debris sparingly on its surface. Here is true glacial "drift" in the sense used by Sir Charles Lyell. The extent of this coastal submergence is obscurely marked by gravelly beaches which range from 150 feet (45 m.) at Newcastle to 195 feet (59·5 m.) at Bathurst.

The Upland of southern New Brunswick.—Bordering the Bay of Fundy coast of the province of New Brunswick, is another upland distiict—the Southern upland—similar in origin and in general form to the Central highland. Its average altitude, however, is lower, being approximately 1,000 feet (300 m.).

Rivers of New Brunswick.—The transverse course of the St. John river, from its head waters in the upland of northwestern New Brunswick across the Central highlands, the Carboniferous lowland and the Southern upland, to the Bay of Fundy shows an extraordinary disregard for structure and for recent topography. The deep intrenchment of the river through the highlands can hardly be explained in any other way than by supposing that it was impressed on the peneplain during the Cretaceous

period. The southeastward direction which the river in general maintains agrees with the southeastward slant of the upland itself, as extended from the 1,700-foot (515 m.) surface of the Central highland across the lowland interval, along the skyline of the 1,000-foot (300-m.) Southern upland, and further, over the Bay of Fundy and along the skyline of the 500-foot (150 m.) upland of Nova Scotia. Other rivers which drain the Central highland, as, for example, the Miramichi, heading in streams which trend parallel to the St. John, turn abruptly towards the northeast where they enter the area of Carboniferous rocks and run out to the gulf down the slope of the lowland. This is probably due to wholesale piracy in the Carboniferous area after the uplift of the Cretaceous peneplain. During the development of the lower Tertiary plain on this transverse belt of soft rocks, the southeastward flowing streams suffered from inroads of the rapidly growing headwaters of the lowland rivers; and the St. John alone remained intact. The broad, deep estuary of the Petitcodiac at the head of Shepody bay occupies perhaps the mouth of one of these master rivers of Cretaceous and of early Tertiary time, whose headwaters now drain out through the Miramichi.

The drowning of the mouths of these large rivers records a downward movement of the coast which affected the whole northern part of the continent. The fiord coast of Maine is a continuation of the ragged coast of the Southern upland. The exact date of the submergence is not known. There is no lack of evidence, however, to show that by the close of the Glacial period the coast had sunk to a level approximately 200 feet (60m.) below its present position.

Upland of Nova Scotia.—The greater part of the peninsula of Nova Scotia is underlain by a complex of ancient rocks. Most of the area exhibits the outcropping edges of a very thick series of slates, associated with a likewise extensive older group of quartzites. During the early Palæozoic these were folded and crumpled into structures so complex that very high mountains must have resulted. At the same time the base of the range was punctured and displaced by enormous masses of granite. Since this mountain building, the surface has been worn down to a plain of low relief. In place of peaks of Alpine form and height there are to-day subdued hills and ridges which range from

600 to 1,000 feet (180 to 300 m.) in altitude. The accordance of the summits of these hills, although not perfect, is so close, particularly in view of the mountain structures which are truncated by the gently undulating surface, that the plateau can be regarded as an ancient plain of subaerial denudation, similar to and contemporaneous with the upland of southern New Brunswick and the peneplain of southern New England. The surface of the upland slopes gently and steadily seaward, from northwest to southeast, as a result of the regional uplift which it has suffered since the period of base levelling.

The upland also presents the appearance of having been carved intaglio. Sunk beneath its surface are valleys too numerous to count. In the higher northern part of the peninsula,—for example, around Arisaig and Antigonish,—the valleys are deep and gorge-like. Farther south, where the plateau is lower, the valleys are shallower and are somewhat obscured by a filling of glacial drift. Here as in other parts of the Appalachian province, the dissection of the upwarped Cretaceous peneplain has been deep and sharp in the elevated interior and shallower and wider near the coast.

The Cobequid mountains, crossed by the Intercolonial railway about midway between Amherst and Truro, may be regarded as a connecting link between the upland of Nova Scotia and the upland of southern New Brunswick. Here, on an outlying mass of hard crystalline rocks, the surface of the Cretaceous peneplain has been preserved while the intervening sediments have been reduced to lower levels.

Cumberland and Colchester lowlands.—The areas occupied by the comparatively weak sediments of Carboniferous, Permian and Triassic age, more especially over the isthmus that ties Nova Scotia to New Brunswick around the head of the Bay of Fundy, are lowlands, half drowned by the sea. Following the uplift of the Cretaceous peneplain, denudation by the rejuvenated rivers, proceeding with far greater rapidity in these areas of non-resistant rocks, developed a secondary peneplain while the areas of harder structure both east and west were left standing as deeply dissected plateau masses. This lower, later peneplain of the Tertiary period extends northwestward along the shore of the gulf, over eastern New Brunswick and Prince Edward Island. Like the older peneplain, this lowland of the Tertiary

cycle has been upwarped and dissected. Nor does this complete its history; for subsequently to its dissection, probably during the Pleistocene, the lowland has subsided, letting the sea up over the lower portions and drowning the broad trunk valleys to form tidal "basins".

It is more than probable that other changes of level have taken place along the coast since the beginning of the Glacial period. The evidence of these later oscillations, however, have not yet been fully gathered and correlated. Extensive plains of stratified sand and clay which cover the lower 100 feet (30 m.) or so of the coast, more especially where rivers formerly entered the sea, appear to be marine or estuarine deposits formed during a period of greater submergence than the present. Wave carved cliffs and wave built beaches, however, if present, are too obscure to justify any statement as to the altitude of the upper limit of post-Glacial submergence. The extreme range of tide complicates the problem. More interesting still is the question of the modern stability or instability of the coast. The salt marshes at Sackville and Dorchester furnish suggestive material for study of this problem. At Fort Lawrence, near Amherst, a buried forest is exposed at low tide beneath 30 feet (9 m.) of marsh mud, and 8 feet (2·4 m.) below mean tide level. While this is indisputable evidence of coastal subsidence, it may date from early post-Glacial time, and proves nothing about modern stability or instability.

Cape Breton.—Separated as it is from Nova Scotia by hardly a mile of water, at the Straits of Canso, the Island of Cape Breton is a part of the province just described. Both the Cretaceous upland and the Tertiary lowland extend over from the peninsula; but the harder and the softer rock structures on which these two physiographic facets are respectively developed are so irregularly distributed over the island that the upland and lowland districts interrupt each other very strongly.

Two areas particularly in which metamorphosed strata and granitic stocks prevail are upland districts; the wide northern arm of the island including most of Victoria county, and the southeastern border of the island east of Bras d'Or lake and south of Sydney. The central portion of the island, on the other hand, from the Sydney district across Bras d'Or lake and northwestward to the gulf, in which soft Carboniferous sediments prevail, is an

undulating lowland. The central part of this dissected lowland, like the coast in Cumberland and Colchester counties in Nova Scotia, has been drowned by depression beneath the sea, forming the Bras d'Or lakes. The largest lake is separated from the ocean at its southern end by a narrow strip of land only a mile wide. The long arms of these lakes and of the peninsulas which separate them are developed along the strike, respectively, of the weaker Palæozoic sedimentaries and the more resistant granitic and metamorphic belts. Great Bras d'Or has a depth of 350 feet (106 m.); Little Bras d'Or lake, 700 feet (215 m.). Not all this depth is necessarily due to coastal subsidence since the late Tertiary dissection; for the island has been glaciated, and the amount of differential erosion below sealevel may have been very considerable.

ANNOTATED GUIDE.

MONTREAL TO LÉVIS.

(G. A. Young.)

Miles and Kilometres.

0. m.
0 km.

Montreal. Leaving Montreal, the Intercolonial railway (from Montreal to Ste. Rosalie, the Intercolonial runs over the Grand Trunk railway) crosses the St. Lawrence river and follows a general northeasterly course through a district underlain by Palæozoic strata, mainly of Ordovician age. The district traversed is a portion of the St. Lawrence lowland or plain which extends far westward up the valley of the St. Lawrence and the Great Lakes. The northwestern portion of the plain is underlain by an apparently conformable succession of Ordovician strata dipping at very low angles to the southeast. The oldest measures are displayed along the borders of the great Pre-Cambrian area to the northwest, while the youngest beds outcrop towards the centre of the plain. Though disconformities presumably exist, the strata appear to afford a complete section of the Ordovician system.

Miles and Kilometres.

The southeastern portion of the plain is occupied by closely folded and faulted measures of Ordovician and, possibly, Cambrian age. These disturbed measures are lithologically and faunally unlike the flat-lying, in part, at least, contemporaneous strata of the northwestern portion of the region. They belong to the geological province which includes the elevated bordering uplands on the southeast underlain by strata ranging in age from Pre-Cambrian to Devonian and which are accompanied by igneous rocks of both volcanic and plutonic types.

The boundary between the gently dipping Ordovician on the northwest and the much disturbed, in part metamorphosed, strata on the southeast, though it traverses the length of the lowlands, is not marked at the surface by any topographical feature. The level, plain-like surface extends uninterruptedly across the boundary which is formed by a zone of faulting, known as the St. Lawrence and Champlain fault. This zone of faulting extends in a nearly straight course northeast from the foot of Lake Champlain to the St. Lawrence river a few miles above Quebec. From there it continues northeastward down the channel of the St. Lawrence. This fault or zone of faulting, first recognized by Sir W. E. Logan, has a length of,
162.8 m. presumably, about 900 miles (1450 km.).
262 km. **Lévis.** (Opposite Quebec city).

QUEBEC AND VICINITY.

(Percy E. Raymond.)

INTRODUCTION.

The beetling cliffs which make Quebec the "Gibraltar of America" have been a puzzle to geologists since the earliest days of the science in America. The "Quebec

*See Map,-Quebec and Vicimty.

group," involved, as it became, with the "Taconic" controversy and the "Theory of colonies," was for many years the subject of hot and world-wide discussion. Such noted men as Lyell, Bigsby, Logan, Billings, Marcou, Selwyn, and Hunt have repeatedly clambered over these rocks, and given to the world the most diverse views as to their age and relative positions. Barrande took a part in the wordy war, and Lapworth furnished one of the most important clues for unravelling the tangle. Although there is still much to be learned, the discovery of fossils and a closer study of the structure have elucidated the main features of the region. To this more recent work, Walcott, Ells, Weston, and Ami have been the main contributors.

The City of Quebec lies principally upon a narrow and high promontory on the north side of the St. Lawrence. To the north of the city is a broad valley, now occupied by the St. Charles river, but which was, at no very ancient date, the main valley of the St. Lawrence. Quebec city thus occupies the eastern point of a long narrow ridge, the western edge of which is at Cape Rouge, 8 miles above the city. To the south of this ridge is the narrow gorge now occupied by the St. Lawrence, and to the north, the broad valley occupied in part by the St. Charles. North and east of the latter valley is the Pre-Cambrian highland, bordered by a narrow belt of Ordovician sediments. South of the St. Lawrence rise the steep cliffs of Lévis. The sediments north of the St. Charles rest upon the Pre-Cambrian, and the oldest are of Trenton (Middle Ordovician) and the newest of Lorraine age (Upper Ordovician). The promontory on which Quebec city is built consists of shale and limestone of Middle Trenton age and the strata on the south side of the river are of Beekmantown age (Lower Ordovician).

The prevailing strike of all the beds is northeast-southwest, magnetic, and the strata are thrown into tightly folded, overturned anticlines and synclines with steep dips to the southeast. There are three major faults approximately parallel to the strike, two of them thrust faults with a heavy throw to the northwest, and one normal fault with a drop to the southeast. The first of the thrust faults occupies the bed of the St. Lawrence

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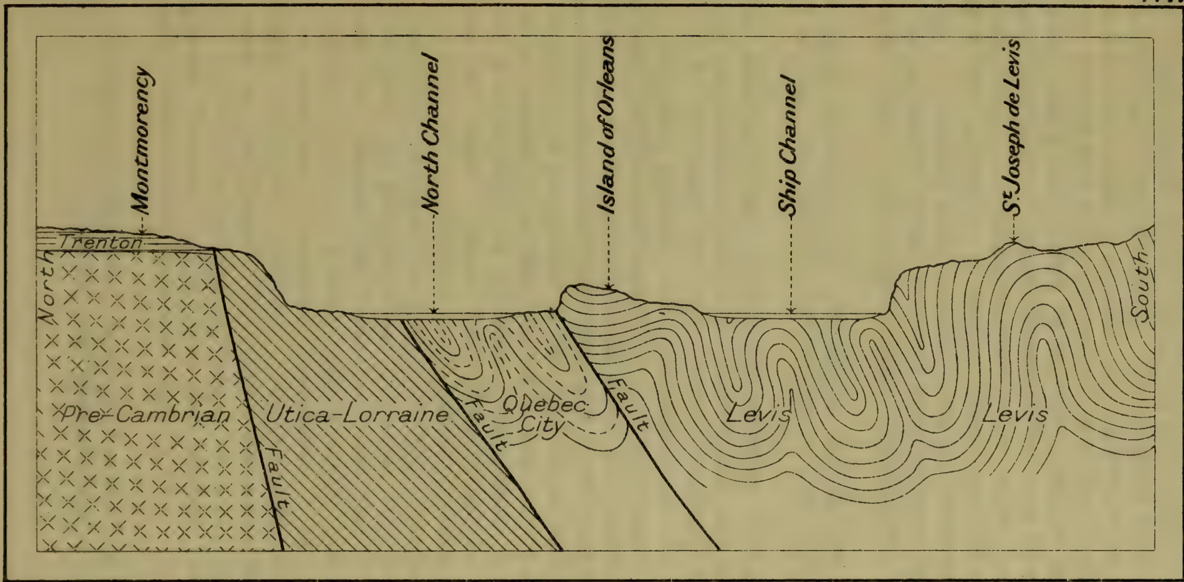

Geological Survey, Canada.

Generalized section across **St. Lawrence Valley**

between Quebec and Lévis, but is seen along the northern side of Orleans island, where the Lévis formation is thrust upon the Quebec city formation. The second fault passes from above Cape Rouge on the St. Lawrence along the northern side of the ridge on which the city is situated and thence along the valley of the St. Charles into the St. Lawrence, where it passes between Orleans island and the north shore at Montmorency. By this fault the Quebec City formation is thrust over the Sillery and Lorraine. The third fault is well shown at Montmorency, where, by a drop of about 600 feet (180 m.) the Lorraine is brought down to abut against the Pre-Cambrian.

The main structure and the faults are shown in the accompanying generalized section across the valley.

In the absence of any detailed knowledge, the amount of lateral movement involved in the thrusts can only be conjectured. It must be very great however, for the Sillery, Lévis and Quebec City formations do not belong to the same province of deposition as the Trenton, Utica, and Lorraine. In the region north of the St. Lawrence the Trenton rests upon the Pre-Cambrian with sponges and corals adhering to the gneiss in the position in which they grew, thus showing that the contact is not due to a fault. Yet, only a mile away, on the Island of Orleans, is a great thickness of older (Lower Ordovician) rocks. Logan explained this by assuming a very great steepness for the shore line here, so that the gneiss of Montmorency was not submerged till Trenton time, but now that we know that both the Quebec City formation and the limestone at Montmorency are of Trenton age, though with hardly a fossil in common, it becomes impossible to accept this explanation. In New York State, the strata containing the same fauna as the Quebec City rocks, lie nearly 50 miles (80 km.) east of the nearest outcrop of strata containing the typical Trenton fauna, but the thrust need not necessarily have been so much as that.

The following formations, amongst others, occur in the vicinity of Lévis, Quebec, and Montmorency.

		At Quebec and Lévis.	*At Montmorency.*
Ordovician	Upper		Lorraine.
			Utica.
	Middle	Quebec City.	Trenton.
	Lower	Lévis.	
		Sillery.	

LORRAINE (FRANKFORT) FORMATION.

The Lorraine in this vicinity, is a fine, soft, grey shale, with thin layers (1 to 3 inches in thickness) of sandstone. There are occasional thicker layers of sand or limestone conglomerate. The thickness is at least 700 feet (215 m.), with the top not seen. Fossils, other than a single species of graptolite, *Diplograptus pristis*, are not common, but a few species, *Triarthrus becki*, *Cryptolithus tessellatus*, *Plectambonites sericeus* and *Dalmanella testudinaria*, have been found.

UTICA FORMATION.

The Utica is a much darker and less micaceous shale than the Lorraine, and contains, besides *Triarthrus becki* and *Leptobolus insignis*, a considerable variety of graptolites, *Climacograptus typicalis* and *Climacograptus bicornis* being the more common. At the base is a small thickness of impure, blocky limestone containing the same fauna, with the addition of a few survivors from the Trenton. The total thickness of the Utica is about 200 feet (60 m.).

TRENTON FORMATION.

The Trenton consists of thin-bedded, dark blue limestone with shaly partings. It is extensively quarried, and used for all purposes, from building stone to road metal.

The Trenton here may be divided, on the basis of fossils, into four zones, all of which can be traced from Quebec to central New York and some of which are

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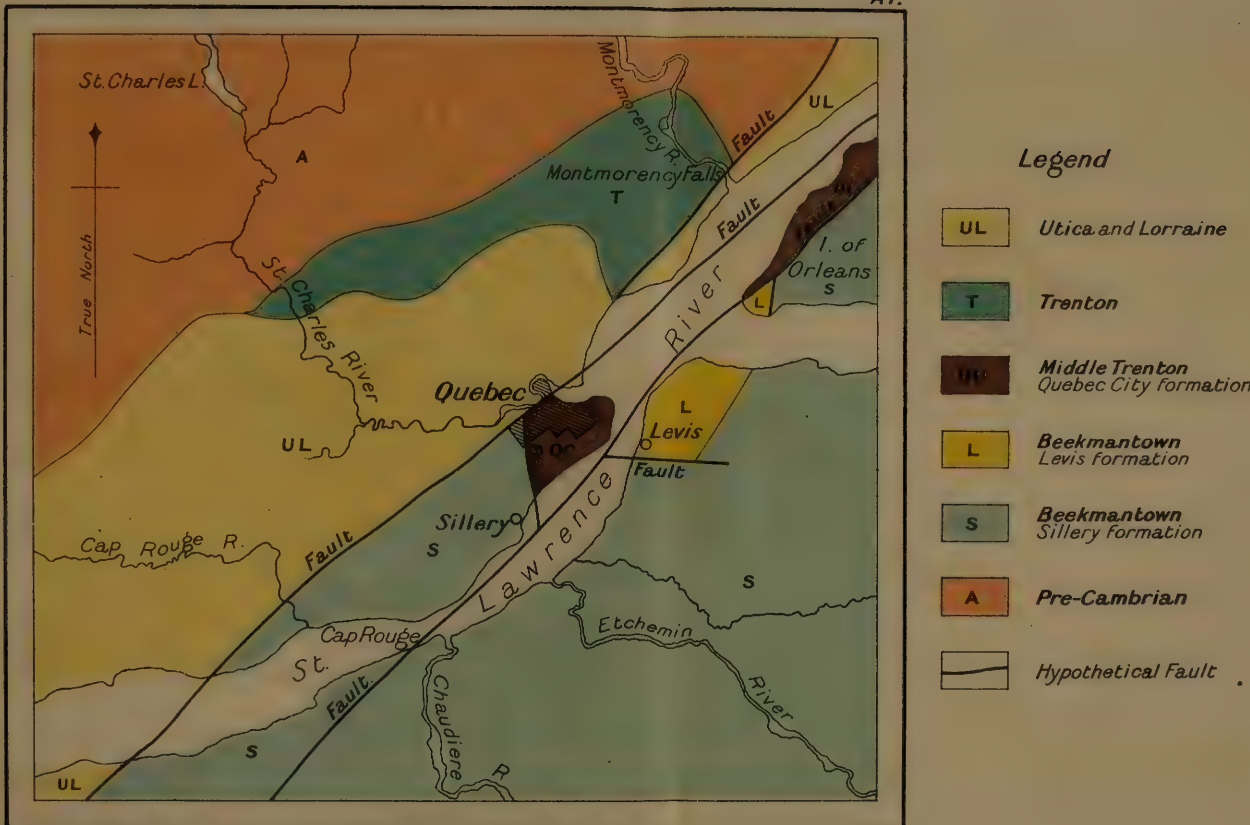
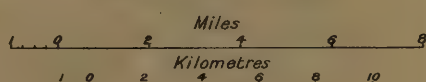


Geological Survey, Canada

Quebec and Vicinity



recognizable as far west as Minnesota. The fossils characteristic of the upper zone are *Prasopora simulatrix* and *Dinorthis meedsi*. The principal fossils of the next lower zone are, *Cryptolithus tessellatus* and *Triplecia nuclea*, while in the zone below is the nautiloid, *Trocholites canadensis*. Finally, at the base, are a few feet of strata with *Parastrophia hemiplicata*. The first fauna occupies the upper four-fifths of the formation, and the last three the lower fifth. The total thickness is about 500 feet (150 m.).

QUEBEC CITY FORMATION.

The Quebec City formation consists of hard, fine-grained limestone, very dark shale, and thick and thin beds of limestone conglomerate. The shales are frequently more or less altered and show secondary cleavage, but sometimes contain rather well preserved graptolites, among them such forms as *Corynoides calycularis*, *Climacograptus bicornis*, and *Cryptograptus tricornis*, fossils which are indicative of a mid-Trenton age. A few fossils other than graptolites have been found, but they are small shells, of no value in correlation.

The pebbles in the conglomerate are quite fossiliferous and contain such fossils as *Plectambonites pisum*, *Tretaspis diademata*, *Lonchodomas hastatus*, and *Nidulites*, all unknown in the typical Trenton. Strata containing these fossils are now known to occur in eastern Pennsylvania and Virginia, where they are found in that part of the Ordovician section which elsewhere is usually occupied by the Black River and Lower Trenton. The thickness of the Quebec City formation is unknown.

LÉVIS FORMATION.

The Lévis formation consists mostly of hard, grey, green, and red shale, thin-bedded hard, blue and light grey limestone, and thick and thin beds of limestone conglomerate. Neither the top nor bottom of the formation is known. About 1,000 feet (300 m.) of strata are exposed in the vicinity of Lévis. The shales contain a graptolite fauna, the more prominent species being *Phyllograptus typus* and *Tetragraptus quadribranchiatus*. The limestones contain *Shumardia granulosa*, *Phyllograptus*,

and *Dictyonema*. The Lévis is thus to be correlated with similar deposits low in the Ordovician of Europe.

Very fossiliferous pebbles have been found in the conglomerates in the Lévis, and the fossils show them to be derived from strata of three geological ages. The pebbles are: 1st, Lower Cambrian limestone with *Olenellus*, *Salterella*, etc.; 2nd, Upper Cambrian or Lower Ordovician, ("Tremadoc" or "Ozarkian") with *Symphysurus*, *Dikelocephalus*, etc.; 3rd, Beekmantown, with *Lloydia saffordi*, *Camarella calcifera*, and a great variety of brachiopods and cephalopods. Besides the limestone pebbles there are many of igneous rocks and quartzites, but they do not form nearly so large a proportion of the conglomerate as do those composed of limestone. The conglomerates also contain pebbles of the red and green shale and sandstone of the Sillery, thus proving that the Sillery is older than the Lévis, while the presence of Beekmantown fossils in both pebbles and matrix of the conglomerates shows that the Lévis is of the same age as the Beekmantown at Philipsburg, Quebec. There are no outcrops of limestone containing the *Olenellus* fauna nearer than Labrador, 500 miles (800 km.) northeast of Lévis; the nearest outcrop of limestone containing the *Dikelocephalus* fauna is at Whitehall, N.Y., 250 miles (400 km.) southwest; and the nearest outcrop of fossiliferous Beekmantown is at Bedford, Que., 150 miles (240 km.) southwest of Lévis. Yet the vast numbers and often large size of the pebbles in the conglomerates indicate that the older limestones outcropped near the basin where the Lévis shales were formed, and it seems very probable that such beds now exist somewhere to the southeast of Lévis, entirely buried by the shales which have been thrust over them.

SILLERY FORMATION.

The Sillery is the oldest sedimentary formation now seen in the district, and very little is known of it. It consists of red and green shales, and lenticular masses of red and green sandstone. Like the Lévis it is thrown into tightly compressed over-turned folds, and contains so few hard beds that it is practically impossible to work out its detailed structure. With the exception of the little inarticulate brachiopods, *Linarssonia pretiosa*, fossils are almost entirely lacking. The few that have been found, species

of *Phyllograptus* and other graptolites, indicate a close similarity to the fauna of the Lévis. The Sillery also contains layers of limestone conglomerate, but the pebbles differ from the conglomerates in the Lévis in containing Lower Cambrian fossils almost exclusively, although an occasional specimen has been found which indicates the *Dikelocephalus* fauna. The thickness of the Sillery is unknown.

HISTORICAL NOTE.

The earliest account of the rocks in the vicinity of Quebec and Point Lévis is in a paper published in 1827 by Dr. J. Bigsby [**1**]. Bigsby divided the rocks into three series, the gneiss, shell-bearing limestone, and a slaty series with conglomerate, and decided that the sedimentaries belonged to the Carboniferous series. Logan [**2**] in 1843, thought that the strata of Lévis were below the limestone north of the St. Lawrence, but finally adopted the view that they were above, and thus the equivalents of the Hudson river and Lorraine of New York State. In 1855, Logan [**3**] believed the Sillery to be the youngest of the formations present, and correlated it with the Upper Silurian "Shawangunk or Oneida conglomerate" of New York.

In 1857, James Hall [**4**] reported on the graptolites of Point Lévis, and referred the shales containing them to the Hudson River group. Billings then took up the study of the fossils found in the conglomerates at Point Lévis, and Logan [**5**] announced in 1860 that Billings had identified these fossils as of Chazy and Calciferous (Beekmantown) age, and that, therefore, the Lévis strata belong at the base of the Lower Silurian. In this paper the term Quebec group was first used and the course of the Champlain-St. Lawrence fault outlined. Marcou, [**6**] in 1862, took exception to the views of Logan, and correlated the strata at Point Lévis with the Georgia shales (Lower Cambrian) of Vermont. Marcou explained the appearance of younger fossils in the conglomerates on the basis of Barrande's doctrine of colonies.

Billings, [**7**] replying to Marcou in 1863, paralleled the strata of the fossiliferous part of the Quebec group with those of the Llandeilo of England and Australia, and the Calciferous and Chazy of America.

In the Geology of Canada, 1863, Logan [8] described the Quebec group in great detail, tracing it from the well known exposures at Point Lévis both east and southwest, where it was supposed to have been altered into a complex series of crystallines. He still believed the Sillery to be above the Lévis, "provided the series was not inverted." He gives a map showing the structure at Point Lévis, and divides the Lévis into 17 zones, with a total thickness of 5,025 feet (1530 m.). The thickness of the Sillery was estimated at 2,000 feet (600 m.).

A comparison of the sections in Canada and Newfoundland led Billings [9] in 1865 to the opinion that the shales at Point Lévis were at least 2,000 feet (600 m.) above the Calciferous (Beekmantown).

Lapworth, [10] in 1886, identified a number of collections of graptolites made by T. C. Weston, and correlated the fauna found at Point Lévis with that found in the Arenig of England. He also studied the graptolite fauna which had been collected in the City of Quebec, and stated that their age was probably Black River or Lower Trenton. The above correlations have since that time been universally adopted.

Ells, [11] in 1888, gave an excellent summary of all work up to that time, a detailed description of the various formations in this region, and many new lists of fossils, the latter determined by H. M. Ami.

A POSSIBLE EXPLANATION OF THE GEOLOGICAL STRUCTURE.

The prevailing strike of all the sedimentary rocks in this area being NE–SW, and the dips generally to the SE, it was at first supposed that the strata formed a regular ascending series from the gneiss at Montmorency to the supposed Upper Silurian red shales of the Sillery south of the St. Lawrence. The discovery of fossils, however, showed this view to be incorrect, and each subsequent collection of fossils has shown the structure to be more complicated than it had previously appeared.

From our present knowledge of the distribution of the faunas it would seem that at Montmorency we are near the southern margin of a great area of Trenton rocks which once extended far over the Laurentian highlands to the north. Infaulted remnants of such an expanse of limestone occur at Lake St. John, 200 miles (320 km.) northeast of Quebec, and at various other places north of the St. Lawrence. This limestone does not seem to have extended to any great distance south of the St. Lawrence, and during Trenton time there was probably a barrier here, to the south of which was a sea containing the Altantic facies of the Trenton fauna (Quebec City formation). South of this barrier Lower and Upper Cambrian, Sillery and Lévis strata had also been deposited but after Trenton time the barrier may have been submerged, so that Lorraine and Richmond shales may have been deposited over both the Trenton and the Quebec City formations.

It is generally conceded that the pressure which accompanied the Appalachian mountain building was exerted largely from the ocean side, and hence all overturning and thrusting at Quebec would be expected to be, as it is, from the southeast. It would seem that when the force was exerted against the great mass of Cambrian and Lower Ordovician strata which had accumulated south of the St. Lawrence, the Lower and Upper Cambrian limestones remained anchored, while the soft Sillery shales allowed the development of a thrust plane within their mass, so that a great thickness of Sillery, Lévis, and Quebec City rocks was pushed toward the northeast from their original position. The drag at the bottom of such a thrust-block would tend to delay the anterior end, thus swelling the strata into an anticline. The front of this block, on reaching the scarps of the normal faults which had developed in this region would be stopped, and the anticline completely overturned and secondary thrust planes developed, so that the lower strata in the block would be thrust over the higher ones. If the greater part of such an overturned and fractured anticline were eroded away, the resulting arrangement of the formations would be such as is shown on the accompanying geological map of the Quebec area. This would account for the fact that the oldest strata, the Sillery, really appear highest in the section, and also for the non appearance of the Cambrian strata from which the boulders in the Sillery and Lévis were derived. It

would also explain the fact that the Sillery and Lévis are much more crumpled and folded than the Quebec City, the latter formation being higher in the block, and so less exposed to friction during transport. It would still further account for the fact that the Quebec City and Lévis are exposed only in narrow bands close to the river, whereas the Sillery forms the greater areas to the south.

BIBLIOGRAPHY

1.	Bigsby, J. T.	Geol. Soc. London, vol. 1, p. 27, 1827.
2.	Logan, Sir. W. E.	Geol. Rept., pp. 18, 19, 1843.
3.	Logan, Sir. W. E.	Esquisse Géologique, 1855.
4.	Hall, James	Can. Naturalist, Vol. III, 1858.
5.	Logan, Sir. W. E.	Can. Naturalist, Vol. V, p. 301, 1861.
6.	Marcou, Jules	On the Taconic Rocks of Vermont and Canada, 1862.
7.	Billings, E.	Can. Naturalist, Vol. VIII, p. 19, 1863.
8.	Logan, Sir. W. E.	Geology of Canada, p. 225, 1863.
9.	Billings, E.	Palæozoic Fossils of Canada, Vol. 1, 1865.
10.	Lapworth, C.	Transactions Royal Soc. Canada, Vol. IV, Sect. 4, p. 167, 1886.
11.	Ells, R. W.	Rept. on Part of Province of Quebec: Part K, Ann. Rept. for 1887–1888.

The graptolites at Point Lévis were described in the following memoir:—

Hall, James.—Geological Survey of Canada. Figures and Descriptions of Canadian Organic Remains, Decade II. Graptolites of the Quebec Group. 1865.

A1.

Geological Survey, Canada

Levis

Feet: 1000 0 1000 2000 3000 4000 5000

Metres: 100 0 500 1000 1500

(Scale of map is approximate)

DETAILED DESCRIPTION

LÉVIS: THE SHALES AND CONGLOMERATES OF THE LÉVIS AND SILLERY FORMATIONS.*

The high bluff on the south side of Main street, Lévis, which runs in a southwest direction from the neighbourhood of the Intercolonial Railway station, is composed of shale, limestone and limestone conglomerate of the Lévis formation. The Lévis formation continues until the turn at Point Lévi is reached, and beyond that point one sees only red and green shale and sandstone of the Sillery.

Along the roadside at Hadlow, there is a cutting in one of the sandstone beds of the Sillery. At this point the sandstone is so folded upon itself as to give the impression of considerable thickness. A few rods back, however, in a ravine which cuts across the cliff, the same sandstone is seen to have a thickness of only about 10 feet (3 m.).

A few rods farther to the southeast, just beyond the ravine, the red and green shales of the Sillery formation are exposed.

From this general neighbourhood an uninterrupted view is obtainable of the bluff on the northern or Quebec side of the river. The structures and formations displayed in this bluff are of great geological interest. The church on the bluff up the river and to the left is at Sillery, the town which has given name to the formation. The red colour of the bluffs at Sillery point can be seen, and the red shale bluffs extend down to the wooded cove which is almost opposite Hadlow. This wooded cove was the landing place of Wolfe's army, and bears his name. There is a fault at Wolfe's cove, and the cliffs from that point to the citadel are composed of hard shales and limestone of the Quebec City formation. The prominent building across the river, on top of the bluff, is the city gaol. To the left of the gaol are the Plains of Abraham, the battle field of 1759. About half way between the goal and the Citadel is the drill hall in the Cove Fields, and it was the excavation for the foundations of the drill hall which furnished the well-preserved graptolites from which the Middle Trenton age of the Quebec City formation was determined. The prominent cliff in line with this building

*See Map--Lévis.

is Cape Diamond, and the rocks of the Cape and east of it are much more massive than those to the west. They are almost devoid of fossils.

At the exposures of the Sillery, on the Lévis side, just northeast of the ravine at Hadlow, the lower part of the cliff is seen to be made up of a bright red shale with green spots and streaks, while the upper part of the bluff is composed of green shale. In fragments of both red and green shale on the talus at the foot of the cliff, specimens of the only common Sillery fossil, *Linarssonia pretiosa*, (Billings) may be found.

From this place as far northeast as Point Lévi red shale and thin sandy beds form the cliff on the southeast.

At Point Lévi, it may be noticed that the red and green shales extend as far as a small ravine close to the street car switch, and that harder grey shales are then encountered. Around the corner, behind the last house of the row to the right are grey shales with occasional bands of red, but beyond this point there is nothing but hard grey shale and limestone. The first impression received is that the Sillery lies above the grey shales, which belong to the Lévis, and that there is a gradation between the two indicated by the alternation of red and grey beds. A closer study of the cliffs, and the distribution of the beds on the flat at the top of the cliff, shows that there is here in reality a marked change along the strike, and that there must be a fault separating the Lévis from the Sillery. There is, in fact, a small slip to be seen back of the easternmost house, and there is evidence of disturbance in the little ravine already referred to.

From Point Lévi to the foot of Davidson street, many folds in the hard limestone are visible in the cliff along Main street.

On the eastern side of Davidson street some distance above Main street and just below the bend in the road, a cutting has revealed the arch of an overturned anticline. The strata here are thin-bedded limestone and shale. The limestone contains *Dictyonema*, *Shumardia* and other fossils and is locally known as the Shumardia limestone. The overturned condition of the strata is well shown here, the dip being uniformly southeast at an angle of 50° except for a short distance at the centre of the arch. The squeezing out of certain beds, particularly a thick shale, is also shown here.

Up the hill, thick beds of limestone are visible back of the little corner house, and between the beds of limestone are layers of shale with *Tetragraptus* and other graptolites.

Continuing up Davidson street to Côte du Passage, across that street and a short distance up a lane, one comes upon a heavy bed of limestone conglomerate with red and green shales on either side. As practically all the measures between this conglomerate and the centre

Anticline in Shumardia limestone. Davidson street, Lévis.

of the anticline are exposed, and as there is no change of dip, it is evident that the conglomerate is above the Shumardia limestone. About 175 feet (53·3 m.) of shale and limestone intervene between the two.

If this conglomerate which may be called conglomerate A, is followed eastward to the next street, it will be seen a short distance up the road from the top of the ruined elevator, and at the corner of the street above is a poor exposure of another conglomerate, marked B on the accompanying map. Descending the hill from Côte du Passage the same shales and limestones noted above the anticline are again observable in rock cuts. The centre of the

anticline lies at the bend in the road and the beds encountered below are a repetition of those above. The thick beds of grey limestone at the foot of the elevator should be noted and compared with those exposed in the cutting at the top of the hill.

From the foot of Côte du passage and Davidson street, northeastward along Main street, two bands of the thin-bedded Shumardia limestone can be seen extending along the face of the bluff to the wooden steps. Here the limestones disappear below the street level, and the axis of the anticline passes to the river side of the road. Between the next two buildings on the southeast, 500 feet (150 m.) east of the steps a fault brings conglomerate A down nearly to the bottom of the cliff, and conglomerate B to the top of the bluff face.

The B conglomerate here is mostly thin-bedded limestone, with a little conglomerate at top and bottom. At the small point just beyond these two houses another fault brings conglomerate A down to the foot of the cliff, and B down against A. Immediately on the point are two other minor slips.

Beyond this point, are the best exposures in the vicinity of Lévis. Conglomerate A, which is 15 feet (4·5 m.) thick at the point where the faults occur, can be traced past the lime kiln at the foot of the bluff, up into the bluff face, where it dwindles to a mere two-foot bed. Above it is a conspicuous layer of thin-bedded limestone, and still higher the thin-bedded limestone of conglomerate B. The latter bed is here quite fossiliferous and contains *Phyllograptus anna*, *Dictyonema*, *Shumardia granulosa* *Lingula quebecensis* and other fossils. In the middle of the cliff, below conglomerate A. is more thin-bedded limestone and the fossils prove it to be the Shumardia limestone, here freed from the effect of the anticline and without the thick beds of grey limestone that are above it on Davidson street. Ten feet below this limestone is a hard grey shale with *Dawsonia*, *Phyllograptus*, *Dichograptus*, and brachiopods.

By following the first street leading southward from Main street at the top of the hill, conglomerate B may be seen in more detail. At first sight this appears to be conglomerate A, but by following it along the surface, with almost every foot exposed, it is seen to run into a thin-bedded limestone at the top of the bluff. Returning

to the cutting on the road, conglomerate A will be seen in place below conglomerate B. The cutting on this road gives an excellent opportunity to study the conglomerate in detail. Many of the pebbles are large, sometimes more than a foot in diameter, usually more or less rectangular and not well rounded. The interstices between the larger pebbles, are filled with smaller pebbles, and there is very little paste. Most of the pebbles are of limestone, and many of them are fossiliferous. The fossils obtained here were chiefly of Beekmantown age. Some of the pebbles are themselves derived from a conglomerate, and others are composed of an oolitic limestone. Besides the limestone, pebbles of gneiss, quartzite, sandstone, and shale may be seen in this exposure.

LÉVIS TO MONTMORENCY FALLS.

An excellent view of Quebec may be had from the ferry while crossing from Lévis to Quebec. On the highest point is the Citadel, while about half way down the cliff is the Dufferin terrace and the Chateau Frontenac. The rocks which form the cliff are limestones and hard shales of the Quebec City formation (Middle Trenton).

After leaving the Quebec Ry. Light and Power Co. railway station, the St. Charles river is soon crossed by the electric tramway and the route proceeds along the low land near the shore until Beauport is reached.

At Beauport (2.8 miles, or 4.5 km.) a quarry in the Trenton limestone shows the strata to be thin-bedded, pure, blue-black limestone with thin shaly partings belonging to the middle division of the Trenton. Immediately beyond this quarry the train leaves the main line of the railroad and begins to mount the terrace. On this rather steep slope a cut has been made, exposing the Utica shale. This shale has a steep dip toward the river, whereas the Trenton strata in the quarry are horizontal. A fault which will be observed at Montmorency, passes between this cut and the quarry. Reaching the edge of the terrace, the railroad crosses the sloping top until it approaches the Beauport-Montmorency highway, which it parallels for the remainder of the distance. Numerous small quarries and lime kilns to the north of the railroad, show the presence of the Trenton limestone along the highway, the railroad itself remains upon the Utica and

Lorraine shales up to a point within a few rods of Kent House at Montmorency Falls. The highway is lined on both sides with the quaint houses of the French Canadians whose long, narrow farms extend to the river on one side and to the Laurentian hills on the other.

MONTMORENCY FALLS: (A) CREST OF FALLS, WESTERN SIDE.*

From this point one gets a good general view of the locality. The crest of the fall is 274 feet (83.5 m.) above sea level ,and the look-out point, on top of the building by the dam, is about 320 feet (97.5 m.)— A.T. In the bed of the river is Pre-Cambrian gneiss, and across the stream, the Trenton limestone is seen resting unconformably upon the gneiss, but with a dip conforming to the slope of the surface of the older rock. Below the falls is a great thickness (700 feet or 215 m.) of thin-bedded, micaceous shale of Lower Lorraine (Frankfort) age, and beneath it, 200 feet (60 m.) of black Utica shale. These shales instead of being nearly horizontal like the limestones above the falls, dip to the southeast at an angle of about 40°. The face of the fall is on a fault plane, and the top of the Trenton, at the base of the fall, is 270 feet (82.3 m.) below the base of the Trenton at the top of the fall, thus indicating a drop to the south of about 600 feet(180 m.) All along the western bank of the stream may be seen the thin-bedded Trenton limestone, which is quite fossiliferous, both near the look-out and at the western end of the road bridge above. The fauna is that of the *Trinucleus* zone, in the lower part of the Trenton.

Across the north channel of the St. Lawrence lies the Island of Orleans, and the low area on the nearer side of that island is composed of graptolite-bearing strata of the Quebec City formation, having about the same strike and dip as the Lorraine on this side of the river, thus implying the existence of a thrust in the bed of the St. Lawrence.

MONTMORENCY FALLS: (B) CREST OF FALLS, EASTERN SIDE.

While crossing the bridge above the falls, the ridges of gneiss on the eastern side of the river, both above and below the bridge should be noted. These ridges show the

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*See Map :—Montmorency Falls.

Geological Survey, Canada.

Montmorency Falls

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Metres

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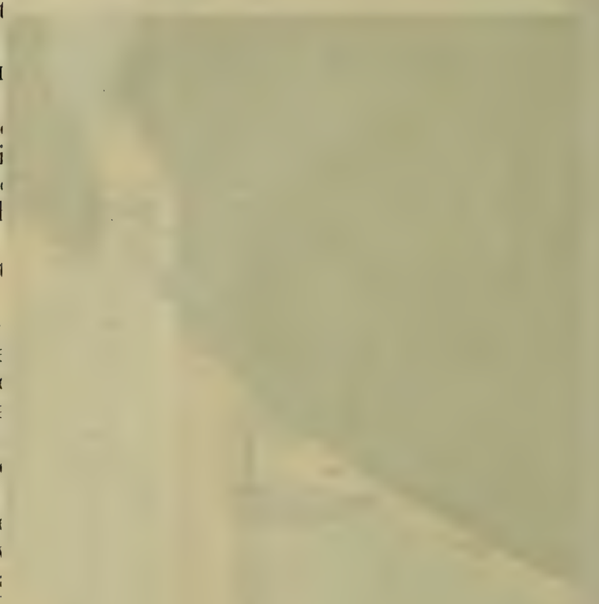
(Scale of map is approximate)



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uneven character of the pre-Trenton surface. At the eastern end of the bridge, a path leads to the exposure on the bank of the river immediately below the concrete dam and just above the crest of the falls. Here the erosion of the rocks have revealed the bottom of the Trenton sea, and one may observe the Solenoporas growing on the sea floor, the calcareous mud filling hollows and cracks in the gneiss, and occasional boulders of the gneiss imbedded in the lower layers of the limestone. It will also be noted that the dip of the strata conforms to the irregularities in the sea floor, and that, while the unconformity here represents all of Cambrian and early Ordovician time, the basal conglomerate is insignificant in amount, indicating that this point was some distance off shore.

These beds are the oldest at this particular point; at the foot of a dam about one-half mile up the stream somewhat older beds outcrop which contain the oldest Trenton faunules, namely those with *Trocholites canadensis* and *Parastrophia hemiplicata*. All of the beds are newer than the Black River. On the weathered surfaces just above this exposure fossils are quite common, *Trinucleus concentricus* and *Eheirocrinus logani* (plates only) being most abundant.

From the crest of the falls on the eastern side of the river it is possible to continue down along the top of this bank, and near the point of the bluff facing the St. Lawrence, fossiliferous gravels of the Champlain period will be found with *Mya truncata*, *Saxicava*, *Macoma*, barnacles, and other fossils. Then, descending the dip slope to near the railroad tracks, one may find specimens of *Triarthrus becki* and graptolites in the Lorraine shales.

MONTMORENCY FALLS: (C) BASE OF FALLS

While descending on the elevator to the basin below the falls the Lorraine shales on both sides of the river may be seen. Proceeding up stream toward the falls, Lorraine-Utica shales are seen in the bed of the stream. Near the base of the falls, the fault-contact between the Utica and the gneiss is crossed. From this point there is an excellent view of the Pre-Cambrian gneiss along the fault plane, and in the direction of Kent House, the horizontal beds of the Trenton may be seen resting on the gneiss. A short distance up the bank on this side a crushed zone within

the Pre-Cambrian rocks indicates a movement parallel to the general fault but the horizontal limestone above crosses this fault plane without interruption, thus showing that it is of pre-Trenton age.

Contact of Trenton and Pre-Cambrian, top of Montmorency Falls.

Across the stream a small gully heading to the east has the gneiss for its northern wall, and at the bottom are a few layers of Upper Trenton limestone, followed by more limestone with *Triarthrus becki* and graptolites. The greater part of the southern wall of the gully however, is shale, and the contact of the Utica and the Lorraine may readily be seen, the Utica shale being much the darker of the two. The contact is a very irregular one, but this irregularity probably does not indicate an uncomformity, but rather that the effect of the fault has been to cause the Lorraine to slip somewhat upon the Utica. The point of rock which is so constantly bathed by the spray is Utica shale, and graptolites, chiefly *Climacograptus bicornis* and *Climacograptus typicalis* are quite plentiful on the side toward the falls. The Lorraine shales are not, in general, very fossiliferous, but certain layers contain a quatity of graptolites and incomplete specimens of *Triarthrus becki*.

SPECIAL POINTS OF INTEREST: QUEBEC CITY.

1. Sous le Cap and Champlain Streets.

Sous le Cap is an exceedingly narrow and not very pleasant street or alley under the cliff and is constantly shown visitors as the "narrowest street on the American continent," or the "narrowest street in the world." Passing close to the cliff it affords an occasional glimpse, on the north, of the shales and limestones of the Quebec city formation. Sous le Cap ends at St. Jacques street, from here, after turning into Sault au Matelot and continuing to Côte de la Montagne, one should turn up the hill and stop a few moments to examine the faulted and crushed conglomerate in the face of the bluff. The pebbles here are quite fossiliferous and contain the Lower Trenton fauna with *Nidulites*, *Ampyx*, *Tetraspis* and other fossils of the Atlantic facies.

Faulting has in large part been responsible for the structure shown in this cliff face, and the first impression conveyed is that this is not a conglomerate, but that the pebbles are due to the disruption of regular layers. After a comparison of this outcrop with others about the city however, it is believed that this is really a conglomerate torn up and softened by the crushing which has taken place in the faulting.

By retraversing Côte de la Montagne and turning into Notre Dame street, one passes the church of Notre Dame des Victoires, built in 1668. At the second corner, by turning into the Cul de Sac, the headquarters during the French regime of the rich pawnbrokers, one reaches Champlain street. Coming out of the Cul de Sac, the vacant space on the left is the old Champlain market. Beyond the Champlain market on the north, above the road, the nearly vertical limestone of the Quebec City formation is seen surmounted by the Dufferin terrace. At the further end of the terrace traces may still be seen of the great landslide of 1881. The strata here have a steep dip into the cliff. The upper ends of the beds formerly overhung the road, but finally they gave way and crashed down into the houses lining the road beneath, killing many people.

Beyond this point the nearly vertical strata, limestone and shale, form a great cliff along the north side of the road. The shale has in places a secondary cleavage.

Although extensive search has been made for fossils along this bluff, the work of various collectors for many years has been rewarded by only one or two badly preserved graptolites.

A tablet on the face of the cliff marks the spot where in an engagement on the last day of the year 1775, the troops from the revolting colonies of America besieging Quebec were defeated with the loss of their leader, General Montgomery.

Beyond this tablet the road follows the foot of the cliff which reaches its highest point at Cape Diamond, where a slight turn in the road shows a change in the strata to thin-bedded dark shales with interbedded sandstone at a flight of steps leading up the cliff. The shales have afforded a few badly preserved graptolites which suggest that the soft shales are of Lorraine age.

2. *The Northern Face of the Cliff separating Upper and Lower Towns.*

The exposures along this cliff may be reached from the Quebec Ry. Light and Power Co. railway station by crossing St. Paul street and proceeding through the side street to St. Valier, nearly parallel to St. Paul. Following St. Valier west, one crosses Côte du Palais near the site of the old Palais gate, thence the route follows along below the wall of Upper Town. To the right of the stone building in the corner of the wall is the site of the Palais of the old French governors of Quebec. On the left, when nearing St. Rich street, may be seen the limestones, shales and limestone conglomerates of the Quebec City formation. A block further along St. Valier street, the strata can be examined in detail at a stairway on Côte à Cotton, the limestone conglomerate being well shown near the top of the steps, just at the base of a retaining wall. Many of the pebbles in this conglomerate are fossiliferous, the fauna being the same as that found in the pebbles on Mountain Hill.

An iron stairway on the left of St. Peters Church gives another good view of the strata. A short distance beyond this stairway at the Côte d'Abraham is an excellent exposure of the conglomerate, from which a large number of fossils have at various times been obtained.

The Quebec City formation is still to be seen at Côte de la Négresse, beyond which point the cliff is partially concealed by buildings and vegetation, but below the Martello

tower and thence to the Boulevard Langelier, the thin-bedded, grey, micaceous shales of the Lorraine are exposed, with much the same strike and dip as the Quebec City formation. Up the hill, above the shales, the harder shales and limestones of the Quebec City formation have been

Crushed conglomerate with fossiliferous pebbles. Mountain Hill, Quebec.

exposed in trenching for city improvements, and the indications are that the Quebec City is thrust over the Lorraine, instead of the two lying side by side, as in a normal fault. The Lorraine here has afforded numerous specimens of *Diplograptus pristis* and small brachiopods of the genus *Dalmanella*.

Continuing along Arago street the bluff may be climbed at Côte Sauvageau, where the soft shale is in marked contrast to the hard limestone and shales seen at Côte à Cotton and Côte d'Abraham.

After climbing Côte Sauvageau to the point of intersection with Reservoir hill, by descending that hill 200 feet (60 m.), the thin-bedded, soft, grey micaceous Lorraine shales will be encountered. Certain layers in this shale contain a great abundance of graptolites.

A hundred feet further down the hill are hard red sandstones, and from that point west the bluff is composed of shale and clay of the Sillery formations, this being apparently the point of exit of the fault which enters the bluff at Wolfe's Cove on the St. Lawrence side of the city.

Returning up the hill, on a path at the right side of the street formed by the junction of the two hill streets, may be seen a thin bed of limestone conglomerate between layers of the shales. A limestone conglomerate in the Lorraine is a very unusual thing, probably never noted outside this particular area.

From this point also, a good view may be had of the broad, flat-bottomed, deserted channel of the St. Lawrence, a branch of which once flowed to the north of the city.

SPECIAL POINTS OF INTEREST: LÉVIS.

Leaving Main street, at the foot of the bluff about 650 yards (600 m.) east of the railway station at Lévis and proceeding eastward along the Intercolonial Railway tracks, it will be noted that the face of the bluff here, is free from the conglomerate. At the left of the track, however, there is a conglomerate (marked C on map) partly submerged at high water, which strikes toward the railway track, and, in the first cutting crosses the track and forms the face of the bluff to the right. This conglomerate is very different in appearance from those to be seen along the cliffs bordering Main street as it contains more matrix and fewer pebbles, weathers to a peculiar brown, is much streaked with calcite, and contains a good deal of sand.

At the end of this little cutting, this heavy conglomerate disappears. On the left hand side of the track the strata are much disturbed, and while there are two lenses of rusty conglomerate on that side, the main mass of conglomerate does not cross. At the right there is a small offset in the bluff, and on the face a conglomerate like the heavy one just mentioned is seen emerging from the bluff. On the top of the bluff, near St. Joseph road opposite the end of Côte des Pères, this conglomerate is seen again, but cannot be traced much further. It seems that the rusty conglomerate has been thrust by another cross fault a little southward.

About 400 feet (120 m.) furthei along the track, there is another offset in the bluff, and again the rusty conglomerate

seems to be thrown southward, and this time it crosses the track in a small cutting, and disappears.

This cutting is one of the best localities for graptolites in this vicinity, and the position of this graptolite bed in the section is therefore of considerable interest. Up the hill from the graptolite bed is a conglomerate band about 100 feet (30 m.) above it. Fortunately this band can be traced with considerable certainty to connect with the lower of the two bands in the bluff section (conglomerate A., see Lévis guide above). It is of course a question whether the graptolite layers stratigraphically belong 100 feet (30 m.) below this conglomerate A, or 20 feet (6 m.) below the rusty one. It seems that the former is the case, because, firstly, there is a zone of badly crushed and slickensided shale between the lower, rusty conglomerate and the graptolite shale, and secondly, the fauna is like that found in the shales of the bluff, *Dichograptus octobrachiatus* and *Phyllograptus anna* being the more characteristic species.

Beyond this cutting, a path leads up through the bushes to the top of the bluff. Near the top of the bluff is a limestone conglomerate similar to one exposed on the street above St. Joseph road. The conglomerate contains thin-bedded layers of limestone. It is here very thick, but this thickening is due to a doubling on itself in a synclinal fold. Following this path southward, to the highway and thence to and along St. Joseph road to Bégin street and up this street, no strata are exposed until a lane is reached leading to the quarries on the hillside, Just at the entrance to the lane a band of limestone conglomerate is exposed, another occurs a short distance further, and a third makes a prominent ridge just north of the quarries which are themselves in a conglomerate.

In the two quarries opened in this highest ridge there are very large masses of limestone, one of them 35 feet (10·6 m.) in diameter. It is hardly possible to consider them boulders, and, moreover, both these larger masses and the brown weathering paste contain fossils of Beekmantown age. Other pebbles in the same quarry contain Upper Cambrian fossils, and there are some large pebbles of sandstone, notably one just at the left of the eastern quarry. The ridge is therefore a conglomerate, but a large part of the material seems to have come from a limestone layer disrupted *in situ*. The first ridge north of this contains the same sort of large limestone masses

with Beekmantown fossils, and it is thought that the two conglomerates are identical, and form the arch of an overturned and eroded anticline. The two conglomerates exposed to the north in the lane are duplicated in the cemetery back of this ridge.

This ridge is the "ridge north of the St. Joseph cemetery" mentioned by Ells, and it was here that Walcott first found fossils in the matrix and was thus enabled to make a definite correlation with the Beekmantown at Philipsburg.

QUEBEC AND VICINITY: PHYSIOGRAPHICAL NOTES.

(J. W. Goldthwait.)

The commanding position of the old city of Quebec, on the heights above the St. Lawrence, affords opportunity for observing to best advantage the broader features of the St. Lawrence plain. From Dufferin terrace and the citadel, as one looks down the estuary, he sees on the left the massive forms of the Laurentian mountains stretching away into the distance behind the north shore. Along their irregular border Pre-Cambrian gneisses disappear under the steeply upturned edges of Palæozoic limestones and shales, showing how the long continued denudation of Tertiary time failed by several hundred feet to reduce the crystallines to the level of the adjoining sediments. Midway in the estuary the Island of Orleans with its flat top 250 feet (76 m.) above the St. Lawrence, appears as a connecting link between the narrow plain that lies at the foot of the mountains on the one hand, and the broad lowland of the St. Lawrence on the other. Beneath the smooth skyline of this St. Lawrence plain the river and its small tributaries are deeply intrenched. Here at the narrowest point on the estuary the Plains of Abraham on the north side and the Lévis hills on the south, stand about 300 feet (90 m.) above tide, with precipitous cliffs bordering the St. Lawrence. From the river southward the plain rises slowly and steadily 12 or 13 miles (19 or 21 km.) before it reaches the first definite line of ridges on the southeast. This great St. Lawrence lowland appears to be a peneplain, like the Cumberland, Colchester, and Eastern New Brunswick lowlands, developed on the soft Palæozoic sediments that lie between

the hard gneisses of the Laurentides on the north and the resistant sandstone belts of the Appalachian ridges on the south. Uplifted, like the other lowlands, in mid-Tertiary time, it has been widely dissected by the river and its tributaries, and subsequently drowned. The tide now runs up the St. Lawrence to Lake St. Peter, 80 miles (128 km.) above Quebec. For at least a part of the Pleistocene period the valley stood even more deeply beneath the sea.

According to Chalmers, the glacial history of this region is very complex; for there seem to have been three systems of land ice in the field: first an ice sheet appears to have spread from the Appalachian highlands of southern Quebec and New Hampshire northward as far as the St. Lawrence; next came an invasion of ice from the centre east of Hudson bay which crossed the St. Lawrence as far east as Quebec but not farther; and finally there is thought to have been a southwesward movement of ice from the Laurentian mountains. Local glaciers seem to have descended from these mountains in the closing stages and floating ice drifted up the estuary, which at that time was much deeper and wider. Marks of this drifting ice are found, at various points on the south shore. The evidences of these several stages or epochs of glaciation cannot be regarded as yet sufficiently in hand to justify conclusions regarding them.

At the close of the last Glacial epoch the region around Quebec stood approximately 600 feet (180 m.) lower than now. By a differential upwarping, the old seafloor sediments and associated shorelines have been lifted to their present height above the sea. The obscure character of these raised beaches suggests that the land was already emerging from the sea when the ice sheet melted away, and that it continued to rise rather steadily and rapidly until approximately the present altitude was established. Gravelly beaches on the hills behind Chateau Richer, 15 miles (24 km.) east of Quebec, stop abruptly at 587 feet (178·9 m.). A similar upper limit to wave-washed deposits appears on the road running inland from St. Joachim, 10 miles (16 km.) farther east, at about 570 feet (173·7 m.). At St. Gervais, 15 miles (24 km.) south-east of Quebec, a well built bar of gravel stands 632 feet (192·6 m.) above the sea. These measurements harmonize with those for the upper marine limit along the south

shore, where the water plane rises steadily towards Quebec all the way from Little Metis. Even though marine shells have been found only part way up to this level, as for instance at 375 feet (114·3 m.) at Portneuf, 30 miles (50 km.) west of Quebec, it seems certain that the submergence registered by the gravels at 600 feet (180 m.) is also marine.

Along the electric tramway from Quebec to Ste. Anne de Beaupré, there is an opportunity to see the Micmac sea-cliff and shelf the strongest and most continuous of the old shorelines of the lower St. Lawrence. In the town of Quebec itself, the twenty-foot terrace is obscured by the streets and buildings of the old town. On the Lévis shore several fragments appear. After crossing the delta-like flats at the mouth of the Charles river, near Beauport, the trolley line comes close up to the foot of the steep sea-cliff of this ancient shoreline. From Beauport all the way to Ste. Anne and St. Joachim, at the end of the railway, the cliff is continuous and nowhere far from the track. It is a precipitous turf-covered bank, from 20 to 50 feet (6 to 15 m.) high. While its course instead of being straight is gently curved, there are no marked irregularities, neither bold headland nor sharp re-entrant. It is a typically "mature" coast. From the foot of the cliff the terrace slants gently outward for several hundred yards to the present high tide mark, and continues in the form of half submerged mud flats for an equal distance offshore. Its total width, from the foot of the bluff to the outer edge of the flats ranges from half a mile to a mile and a half (0·8 to 2·4 km.). Across the channel, on the north side of Orleans island, one can see a similar shelf and bluff. This extends completely around the island.

At a number of points along the railway it is possible to see that the cliff has been cut back not simply in glacial drift, but in hard rock. At Eglise de Beauport, for instance, fresh cuts in the face of the Micmac bluff show soft slates dipping seaward at a steep angle, nearly coincident with the slope of the bluff itself. One might conclude that the escarpment was not a wave-cut cliff but merely a structural one, if he saw it at this locality only. At Montmorency Falls, likewise, the red shales, deeply decayed, appear behind the cliff in cross-section in the walls of the gorge. The fall itself lies on the boundary between these shales

and the more resistant gneisses, upon which the river has been held, while it has excavated the deep gorge in the shales below. Continuing along the inner edge of the Micmac terrace to Chateau Richer, the railway passes in sight of quarries on the face of the bluff where limestone instead of shales are exposed. Clearly the bluff has been trimmed back into the coast without regard for the strike or the dip of the rocks. Beyond here the terrace broadens and runs uninterruptedly for many miles.

Two facts about this Micmac shore line are pre-eminent in importance. First, its strength, in view of the narrow limits within which waves could develop between the Island of Orleans and the north shore, is extraordinary. It has been cut back as far into the coast as the distance across the shelf,—or over half a mile. Secondly, the altitude of the shelf here near Quebec is almost exactly the same as its altitude 300 miles (480 km.) down the estuary; and in the interval there are no signs of local warping. This recent emergence of the coast of the lower St. Lawrence within the limits stated was a perfectly uniform uplift.

A study of the flora of the Micmac terrace at Ste. Anne de Beaupré shows a striking intermingling along the high tide zone of salt marsh plants and fresh water plants. This might be interpreted to mean that the fresh marsh is gaining on the salt, and that the plants from the inner marsh are advancing out over the tide marsh as fast as the coast rises. On the other hand, it might be interpreted to mean that the salt marsh plants are invading what was formerly fresh marsh, during a slow subsiding of the coast. And finally, it is possible to regard the intermingling of the two flora as the result of the varying effects of high tides and seasons of heavy rainfall, which now flood the marsh with salt or brackish water and then fill it temporarily with fresh. So far as can yet be discovered, there is no way to demonstrate whether the Micmac shelf is still slowly emerging from the sea, or is stationary, or is slowly subsiding. In general recently collected facts from the New Brunswick and New England coast favour the idea that no change of level has occurred during the last few thousand years.

ANNOTATED GUIDE.

LÉVIS TO RIVIÈRE DU LOUP.

(G. A. YOUNG.)

Miles and Kilometres.

0 m.
0 km.

Lévis (opposite Quebec city)—Alt., 15 ft. (4·5 m.). Leaving Lévis the Intercolonial railway for a short distance closely follows the St. Lawrence shore. It then leaves the river and passing out of the circumscribed area of the Lévis formation, climbs the sharp rise to the level of a rolling, plain-like area underlain by the red and green slates and sandstones of the Sillery formation which customarily has been assigned to the Upper Cambrian though probably of Ordovician age.

The Sillery measures outcrop over a zone having a width varying between 6 miles and 20 miles (9·7 km. and 32·2 km.) and border the St. Lawrence river from the vicinity of Quebec northeastward to beyond Rivière du Loup, over 100 miles (160 km.) away.

To the southeast, the Sillery strata are bordered by a narrower zone of dark slates and quartzites that conformably underlie the Sillery. The Sillery and the underlying formation are strongly folded along axes running nearly parallel with the general course of the St. Lawrence. The folds are asymmetrical, the northwestern limbs being steeper than the southern, and in most places the folds are overturned giving a southeasterly dip, generally with angles of 75° or more.

Within the relatively wide band of the Sillery bordering the St. Lawrence are detached, elongated areas of quartzite and conglomerate composing the Kamouraska formation. These areas vary in length from 10 miles (16 km.) or more down to a fraction of a mile. Their major axes strike approximately parallel with the general strike of the surrounding Sillery. The areas of the Kamouraska are mainly confined to a zone about 45 miles (72 km.) long, bordering the St. Lawrence and situated midway between Quebec and Rivière du Loup.

Miles and Kilometers.

The Kamouraska measures form a series of detached hills seldom rising more than 300 feet (90 m.) above the surrounding country. The strata are sharply folded into anticlines, slightly overturned to the northwest, and pitching both to the northeast and southwest. The conglomerates in places contain limestone pebbles holding Cambrian and in some cases possibly early Ordovician faunas.

The Kamouraska formation has been held by some authorities to be an integral part of the Sillery. J. A. Dresser has, however, brought forward arguments tending to show that the Kamouraska unconformably underlies the Sillery.

For the greater part of the distance between Quebec and Rivière du Loup, the broad band of Sillery is travesred by a zone of overthrust faulting with the downthrow on the northwest side. The fault zone is marked for a length of 65 miles (105 km.) by a well defined escarpment which at the point of the maximum development rises 700 feet to 1,000 feet (215 m. to 300 m.) in a distance of 1 to $1\frac{1}{2}$ miles (1.6 km. to 2.5 km.). This fault escarpment, begins not far from Quebec city and with a curving, irregular front extends northeastward parallel with the St. Lawrence and at a distance inland of 3 to 8 miles (4.8 km. to 13 km.). From the foot of the escarpment a low, fairly level area broken only by a few sharp hills, extends to the St. Lawrence. Inland from the top of the escarpment a rolling upland extends to the southeast for distances of 15 miles to 20 miles (24 km. to 32 km.).

At intervals along the railway route from Quebec eastward, views are obtained of the margin of the Laurentian upland bordering the north shore of the St. Lawrence river. This upland, the Pre-Cambrian protaxis of the continent, rises abruptly from the shore of the river, to heights of 1,000 to 2,000 feet (300 m. to 600 m.). Though in places the upland is rugged and of a mountainous character and though it is

Miles and Kilometers.

nearly everywhere traversed by deeply incised valleys, yet, in general, the upland surface is of the nature of a rolling plateau. At widely separated intervals the foreshore is formed of a narrow fringe of Palæozoic strata, but, elsewhere the Pre-Cambrian rocks directly border the river.

The following note relating to the Glacial and post-Glacial features of the district traversed by the railway between Lévis and Rivière du Loup has been furnished by J. W. Goldthwait.

"In the vicinity of Lévis the eastern edge of the St. Lawrence plain or lowland lies about 13 miles (21 km.) to the southeastward. Beyond this the land rises in a series of ridges which to the northeast gradually approach the St. Lawrence shore. This line of ridges during the period of submergence following the Glacial period formed the shore against which the sea formerly rested. At times a distant view of these hills from the train discloses horizontal benches and lines of low cliffs on the wooded slopes, not unlike certain wave cut benches around the extinct Great Lakes in Ontario. The benches which overlook the marine plain, however, are outcropping rock escarpments, along which proofs of wave action are generally lacking. It is doubtful whether the sea stood long enough at any one time previous to the Micmac stage to cut such sea cliffs. The altitude of the upper marine limit has been satisfactorily determined however, by means of fragmentary benches which harmonize with a gently inclined plane dipping towards the northeast as the following measurements show: St. George eight miles south of St. Charles Junction, 630 feet (192 m.); Montmagny, 543 feet (165.5 m.); L'Islet, 514 feet (156.7 m.); St. Jean Port Joli, 513 feet (156.4 m.). In places, at least, below the level of marine submergence, glaciated surfaces indicate an ice movement straight up the estuary southwestward. The surface of the plain is strewn with crystalline boulders from the Laurentian mountains. Above the level of marine submergence, ground

Miles and Kilometres.

moraine and roches moutonnées and other marks of glaciation appear to indicate an eastward movement of the ice sheet."

13.5 m. 24.14 km. **St. Charles Junction**—Alt. 293.5 ft. (89.5 m.). Beyond St. Charles Junction, as the railway descends to the crossing of River Boyer, glimpses may be obtained of the summits of ridges to the southeast, appearing blue in the distance. The front of these ridges marks the position of the zone of faulting that traverses the Sillery area.

23.4 m. 37.7 km. **St. Valier Station**—Alt. 156 ft. (47.5 m.). Approaching St. François, the high ridge that bounds the rolling, plain-like area traversed by the railway, gradually approaches the railway and increases in altitude. Near St. François, the red shales of the Sillery are displayed in a railway cutting.

28.5 m. 45.8 km. **St. François Station**—Attitude 134 ft. (40.8 m.).

36.7 m. 59.1 km. **Montmagny Station**—Alt. 55 ft. (16.8 m.). Just beyond Montmagny, the railway crosses River du Sud and passes close to the St. Lawrence shore. To the southeast, the country rises rapidly for 3 to 4 miles, (5 to 6.5 km.) in a succession of broken ridges to the borders of a highland with a general elevation of 600 to 1000 feet (180 m. to 300 m.).

59.1 m. 95.1 km. **St. Jean Port Joli Station**—Alt. 176 ft. (53.6 m). The high ridges, which continue to rise close to the southeast of the railway, are in part underlain by the Kamouraska formation.

66.1 m. 106.4 km. **Ste. Louise Station**—Alt. 119 ft. (36.3 m.). Beyond Ste. Louise station isolated, abruptly rising ridges of the Kamouraska formation occur on the northwestern side of the railway.

78 m. 125 km. **St. Pacôme Station** — Approaching St. Pacôme, the sillery sandstones and shales are exposed in rock cuttings.

79.7 m. 128.6 km. **Rivière Ouelle**—Alt. 48 ft. (14.6 m.).

94.8 m. 152.5 km. **Ste. Hèlène**—Alt. 323 ft. (98.4 m.). From Ste. Hèlène to Rivière du Loup the railway traverses a relatively flat area gradually rising

Miles and Kilometres. inland. The sharp isolated ridges of the Kamouraska strata no longer occur and the quick rise to the south has disappeared.

102.7 m. 165.4 km. **St. Alexandre Station**—Alt. 370 ft. (112.8 m.). "The altitude of the station here is only about 20 feet below that of the uppermost marine beach; and the gentle seaward slope of the plain, with full exposure to the north, offers unusual opportunity for the construction of a beach at this level. From the car window, after the train leaves the station, one can easily see two low, but persistent, gravelly beaches in the fields beside the track, to the south, which run parallel to it for a mile or more. The high broad ridge on whose outer slope they lie is a till-covered ridge of bed rock,—not a beach." (Note furnished by J. W. Goldthwait.)

114.5 m. 184.3 km. **Rivière du Loup**—Alt. 315 ft. (97 m.).

RIVIÈRE DU LOUP.*

(G. A. Young.)

INTRODUCTION.

Riviére du Loup and the adjacent districts are situated within the belt of folded and faulted strata of debatable age that borders the south side of the St. Lawrence river and gulf, from above Lévis to the extremity of Gaspé Peninsula, a distance of about 350 miles (560 km.) These measures belong to the somewhat vaguely defined assemblage of formations known as the Quebec group. The strata of the Quebec group extend southwestward past Lévis to the International boundary and beyond, and in this southwestern extension of the group, it has been possible from palaeontological and other evidence to indicate the existence of many formations ranging in age from Pre-Cambrian to Devonian. In the northeastern extension, however, along the border of the St. Lawrence below Lévis, there does not appear to be the same complexity since by nearly universal consent it has been agreed that the strata

*See Map—Riviére du Loup.

in general belong to one sub-group including members of Cambrian and perhaps early Ordovician age.

The strata in the immediate vicinity of Rivière du Loup have never been described in detail. Logan [**4**, p. 259] merely states that between the coast at Riviére du Loup and Temiscouta lake, "a distance of about 30 miles (48 km.) which is the whole breadth occupied by the Quebec group in this part, no rocks are exposed of a horizon lower than a quartzite formation considered to underlie the Sillery." By Logan, [**4**, p. 233] the Quebec group was tentatively supposed to be of Lower Ordovician age. The quartzites which were thought to underlie the Sillery are stated to have, in other districts, conglomerates with pebbles of limestone, associated with them. The Sillery was tentatively assumed to form the upper member of the Quebec group.

In a succeeeding report [**5**, p. 4], Logan definitely divided the Quebec group into three formations which, in ascending order, were termed, Lévis, Lauzon and Sillery. The Lévis formation was stated to be of about the horizon of the upper part of the Calciferous (Beekmantown).

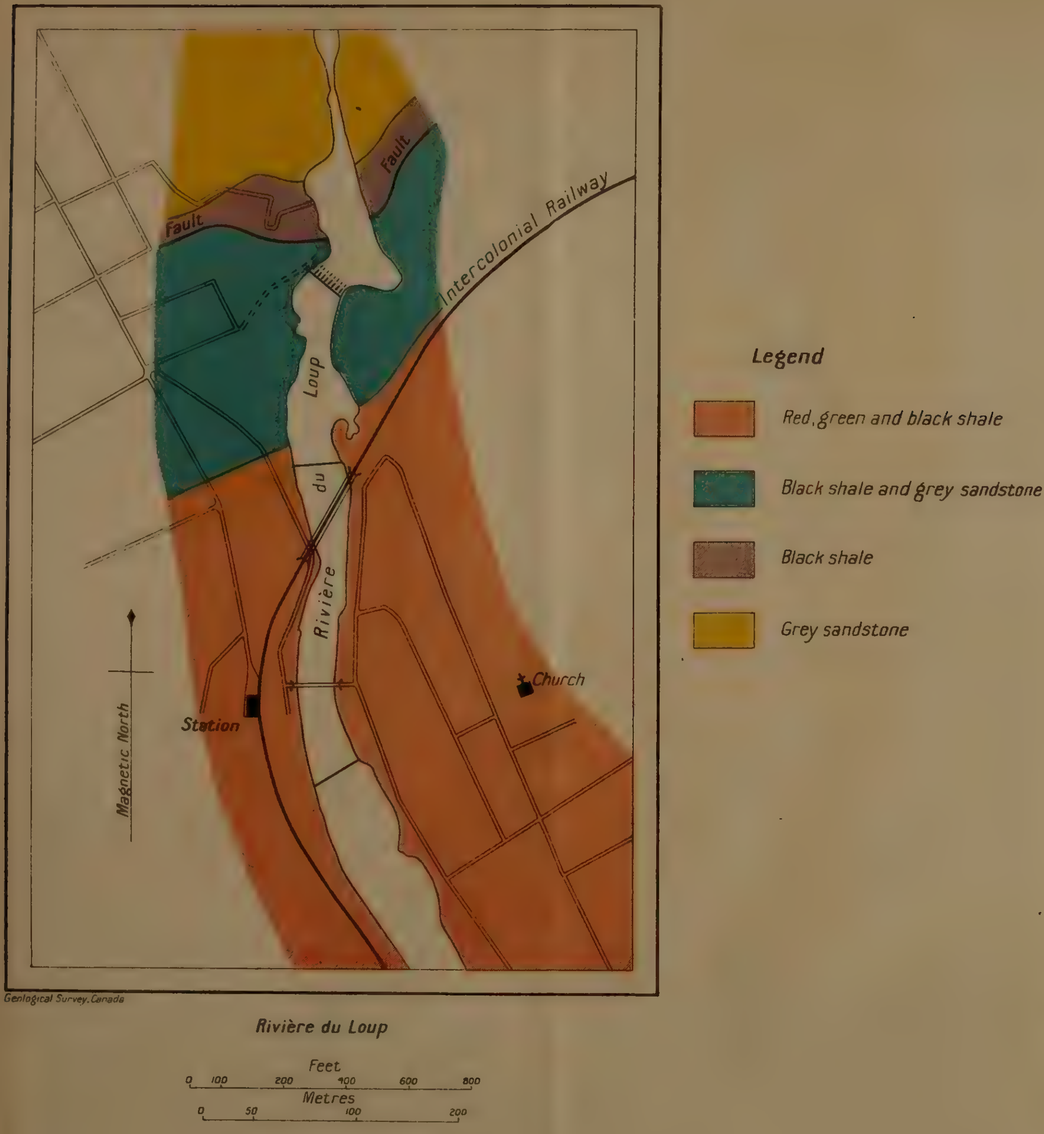
In the years 1867 and 1868, James Richardson geologically mapped a large area on the south side of the St. Lawrence, extending from above Lévis northeastward to beyond Rivière du Loup. In this general area, Richardson concluded that besides formations belonging to the Quebec group, there was also a development of measures uncomformably underlying the Quebec group and to these older strata he applied the name Potsdam (Upper Cambrian). [**6**, p. 120]. To the Potsdam were assigned the quartzites, etc., which were described by Logan as occurring beneath the Sillery in the Rivière du Loup district and elsewhere. By Richardson the Potsdam was divided into three horizons of which the upper was described as formed of light coloured quartzite passing in places into grey, quartzose sandstone, while in places black shales occur interstratified with the whole mass and at the base is a variable thickness of conglomerate holding limestone pebbles. This division of the Potsdam was stated [**6**, p. 128] to cross Rivière du Loup in a narrow strip just below the High Falls and to be succeeded down stream, by a lower division of the so-called Potsdam. The escarpment which causes the High Falls, was stated to be composed of Lauzon (Quebec group) measures with probably a little of the

Lévis at the base, and it was said that these measures overlie the quartzite of the narrow band of Potsdam below the falls [**6**, p. 132]. The Lauzon is described as consisting of green and red shales with bands of gray sandstone and beds of limestone conglomerate. These calcareous measures were said to be fossiliferous in places, as in the case of an exposure on the banks of Rivière du Loup near the railway station.

During the two decades following 1868, various workers were engaged on problems connected with the Quebec group as developed throughout the long belt occupied by this assemblage. As a result of this long continued effort, radical changes were made in the general conception of the nature and composition of the group. A brief abstract of the views held from time to time has been given by R. W. Ells (**3**). As regards the development of the Quebec group in the area to the northeast of Lévis, the main conclusions arrived at were, that the Sillery was older, *not* younger than the Lévis; the Lauzon division was merged in the Sillery; the Sillery was considered to be of Upper Cambrian age, and the Lévis to be of Lower Ordovician, pre-Trenton age. A division of the Cambrian older than the Sillery was also recognized as existing in the same general region. In the neighbourhood of Rivière du Loup, however, Richardson's subdivisions were discarded and the whole group of strata were referred to the Sillery [**3**, pp. 67-70]. The measures thus treated included the quartzites which both Logan and Richardson had separated as underlying the Sillery.

In a later report by L. W. Bailey and W. McInnes [**1**], the character and structure of the Quebec Group strata as developed over a large extent of territory east and northeast from Rivière du Loup is described, and the conclusion arrived at that virtually all the strata belong to the Sillery division and are arranged in overturned folds with prevailing southerly dips and traversed by thrust faults. It is specifically stated [**1**, p. 22], that there is no apparent reason for the separation as Potsdam of any portion of the strata in the vicinity of Rivière du Loup from any other portions of the series.

Recently, in 1908, J. A. Dresser carried a geological reconnaissance over the greater part of the belt of the Quebec Group lying between Lévis and Rivière du Loup. The results of this work are expressed on a map [**2**] on which



Rivière du Loup

(Scale of map is approximate)

however, the geological colouring stops short of Rivière du Loup. It is evident, however, from a consideration of the general geological structure of the region, that according to the views of Dresser, the district in the neighbourhood of Rivière du Loup, is in the main underlain by the Sillery. In the geological legend of the map by Dresser, the Sillery is classified as being of Cambrian age. In the general Sillery area, are isolated areas of quartzites and conglomerates with pebbles of limestone, etc. These rocks are distinguished as forming the Kamouraska formation and by Dresser are considered to be older than the Sillery and possibly to underlie the Sillery unconformably. The areas of the Kamouraska formation as mapped by Dresser, in a general way correspond to one of Richardson's Potsdam divisions, the division to which Richardson assigned the band of quartzite crossing Rivière du Loup below High Falls. It is believed, however, that Dresser would not correlate the quartzite outcropping on Rivière du Loup with the Kamouraska formation.

DETAILED DESCRIPTION.

The foregoing statements present in a generalized fashion, the views previously published regarding the age of the strata occurring at Rivière du Loup in the immediate vicinity of High Falls. In the following statements is given an account of the strata and their structure as observable in a general section along both banks of Rivière du Loup from the neighbourhood of the railway station to below High Falls. The section illustrates, in a general fashion, the nature of a portion of the original Quebec group and of the difficulties in the way of a complete unravelling of the various problems involved.

On lithological and structural grounds, the strata of the section under description are divisible into four groups. The succession descending the river is as follows:—

1. Red, green, and black shale.
2. Black shale, and sandstone.
3. Black shale.
4. Grey sandstone.

By Logan the first three divisions (Nos. 1 to 3) were placed in the Sillery and supposed to be of Lower Ordo-

vician age since the Sillery was thought to overlie the Lévis. By Logan, the grey sandstone (No. 4) was thought to be possibly older than the Sillery. By Richardson, the first three divisions (Nos. 1 to 3) were assigned to the Lauzon (a subdivision of the original Sillery) but guided by the assumed general structure, it was thought possible that the lower portion of the three divisions (Nos. 1 to 3) might be Lévis. The age of the first three divisions was thought to be Lower Ordovician, while division 4 was assigned to the Potsdam (Upper Cambrian) and thought to unconformably underlie the upper three divisions. By Ells, and later by Bailey and McInnes, the four divisions were classed with the Sillery now thought to underlie the Lévis and to be of Upper Cambrian age.

The strata of division 1 as displayed in the neighbourhood of the railway station and along certain streets east of the river, consist chiefly of red, green, and black shales with beds of sandstone and occasional beds of limestone or limestone conglomerate. The strata uniformly dip in a southeasterly direction at angles varying between 45° and 80°.

On the east side of the river along the street leading southerly from the highway bridge over the stream, are outcrops of banded red and dark shales followed by thin bedded, dark grey shales and grey sandstones. The strata dip S. 30° E.,* angle, 70°. Farther on approaching the first street leading to the east, relatively wide bands of red shale alternate with others of a dark grey colour. These are followed by a 20-foot zone of thin limestone beds alternating with dark shales.

On the street leading to the east and past the first road leading to the north, are exposures of banded, red, green and dark purple shales. The strata dip S. 35° E. On the second road leading to the north, no exposures occur until a point is reached about opposite the church. From this point northwards to the end of the street, there is a long series of exposures showing the general character of the rock assemblage.

From this general neighbourhood a splendid view is obtainable of the Laurentian mountains bordering the north shore of the St. Lawrence, 20 miles (30 km.) away.

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*All directions of dip are referred to magnetic meridian.

The strata along the above mentioned street from just beyond the church northward to the end of the road, dip in general to the southeast at angles varying between 50° and 70°; that is, if the strata be not overturned, they are displayed in descending order, if traversed in a northerly direction. The first exposures consist of hard, light grey sandstone in beds varying in thickness from 6 to 18 inches (15 cm. to 45 cm.). Beyond this the outcrops consist chiefly of red, green and dark shales, the red varieties predominating. In places the colours rapidly alternate in thin bands, in other places the colour bands are several yards or more wide. Towards the end of the street, where it joins the road leading along the river to the highway bridge, the strata are plicated, perhaps having been involved in a fault zone.

The banded shales are exposed from the end of the street to the railway and there form a long rock cutting. The strata in the railway rock cutting consist of red, green and dark shales with occasional thin beds of sandstone dipping to the southeast at angles varying from 45° to 65°. At two points in the cutting occurs calcareous conglomerate holding pebbles of limestone. At one place, the conglomerate forms a thin, lense-like body, in the other it forms a bed 3 inches (8 cm.) thick. A somewhat similar conglomerate occurs on the west bank of the river opposite the railway station, where the bed is about 4 inches (10 cm.) thick and is associated with dark and red shales. A similar conglomerate outcrops along the railway, south of the station. The following note regarding certain fossils occurring in these conglomerates has been furnished by Dr. Percy E. Raymond.

Note on fossils at Rivière du Loup, Que. By P. E. Raymond.—"Interbedded with the red and green shales at Rivière du Loup are thin layers of conglomerate, the pebbles of which are largely of a grey limestone. Fossils may be found in the pebbles in at least two localities, one on the west bank of the river about 100 feet (30 m.) south of the highway bridge, and the other on the west side of the railroad tracks just south of the engine house. The fossiliferous pebbles are very small, and the fossils fragmentary and unsatisfactory. Pieces of two Orthoids one of them with simple plications, are common at both localities, as are also fragments of the stems of some Pelmatozoan, more probably a crinoid than a cystid. The

most important specimens are two fragmentary Illaenus-like trilobites. These belong to an undescribed genus and species, but the same form is known from the Upper Cambrian of Missouri. This same species was found in a similar conglomerate at St. Phillip de Neri, 31 miles (50 km.) west of Rivière du Loup, but at that locality the greater number of the pebbles contained fossils of Lower Cambrian age, while at Rivière du Loup, no definitely Lower Cambrian fossils have been found. The Upper Cambrian age of the pebbles in the conglomerates is indicated by all the fossils so far found here. In what seem to be these same shales at St. Pascal, Richardson many years ago found graptolites of Beekmantown (Lévis) age''.

The evidence of the fossils as given above by Dr. Raymond indicates that the strata of division 1 are not older than Upper Cambrian and that they may be of Beekmantown age.

The boundary between the strata of division 1 and those of division 2 which outcrop along the river below the railway bridge, has been somewhat arbitrarily chosen. From the road which leads from the railway station northwards along the west bank of the river, the red shales and associated strata of the rock cutting along the railway on the east side of the river, are visible, From this road beyond the railway crossing, an occasional glimpse of the red shales outcropping along the river below the railway may be obtained. At a point a short distance below the dam, the red strata abruptly cease and are succeeded by dark rocks which belong to division 2 and outcrop along both banks of the river to a point below the falls.

The strata of division 1 outcropping along the east side of the river below the railway bridge consist of dark shales with sandstone beds and zones of red shale dipping upstream at high angles. What seems to be a minor fault bounding a zone of red shales has been chosen as the boundary between divisions 1 and 2. On the north side of this fault, the strata of division 2 consist of dark, nearly black shales with thin beds of grey limestone, ½ to 1 inch (10 to 25 mm.) thick, dipping upstream at an angle of 60°. The thin limestones, in places, are disrupted and form lenses. Below this point, as far as the brink of the falls, the strata with the exception of several minor bands of red shales, consist of dark shales interstratified with beds of light

coloured, fine grained, quartzose sandstone. At the beginning of the section, the sandstone beds are thin, in most cases from $\frac{1}{2}$ to $1\frac{1}{2}$ inches (10 mm. to 40 mm.) thick, while farther down stream, the sandstone beds bulk more largely and in places are 6 feet (2 m.) thick. The strata in general dip upstream at comparatively low angles, but in places, are crenulated.

The general character of division 2 and its relations with the remaining divisions, may be seen to advantage in the walls of the gorge of the river below the falls. The route to the foot of the falls passes northward through the town and thence by a side street joining a winding road leading down into the gorge of the river. No exposures occur in this part of the town, but presumably it is underlain by strata of division 2. The winding road, leading from the town street, first runs southerly towards a low escarpment whose bare rock face is formed of nearly horizontal dark shales with beds of light coloured sandstone. These measures belong to division 2. They repose on strata of division 3, but are separated from them by a nearly horizontal thrust plane which must lie about at the foot of the escarpment.

At the first bend in the road, in front of the escarpment, and again a short distance farther on, are outcrops of a light coloured, greenish-grey, quartzose sandstone dipping to the southeast, towards the escarpment, at an angle of about 30°. This sandstone belongs to division 4, and in the exposureless interval between its outcrops and the face of the escarpment, must lie the strata of division 3.

The strata of division 3 are displayed along the road from a point near the second exposure of sandstone, to near the end of the road at the river side. In the first exposures, the strata dip southwards at angles of about 45°. The rocks consist of dark shales with thin sandstone beds $\frac{1}{2}$ to $1\frac{1}{2}$ inches (10 mm. to 40 mm.) thick. As the road is descended, there may be seen in the high rock escarpment the trace of a thrust plane along which the strata of division 2, have been pushed over those of division 3. The fault plane dips towards the south at an angle of about 20°. The overlying strata of division 2, are nearly horizontal, the underlying strata (division 3), are steeply inclined and, in the neighborhood of the fault, are crumpled and torn.

From the underlying shales of division 3, Dr. Raymond has collected fossils of a single species, regarding which he makes the following note. "The small flattened oval fossils are *Caryocaris curvilineatus*, Gurley. Both genus and species are confined, in this general region, to rocks of Lévis age. The species has been found at Point Lévis, Deepkill, near Albany, N. Y., and in Nevada, while the genus occurs also in the Skiddaw slates of England and Australia."

The finding and identifying of this fossil corroborates in a certain measure Richardson's suggestion that possibly these underlying measures might belong to the Lévis, though Richardson's belief was founded, as it is generally supposed, on a mistaken supposition regarding the relative ages of the overlying and underlying strata.

From the edge of the river, the trace of the thrust plane is visible in the cliff face rising from the opposite shore. The overlying strata of division 2, may be seen to be thrown into a series of crenulations clearly and strikingly expressed by the banded character of the measures. The regularly-formed crenulations or plications, perhaps average 4 to 6 feet (1·2 to 1·8 m.) from crest to crest. These crenulations extend up the whole height of the high, cliff face. Along this rock face upstream, the plications gradually fade away and towards the head of the rock-walled, amphitheatre-like embayment, the strata dip regularly to the southward at angles of from 35° to 45°. The strata of division 2, thus exposed at the head of the amphitheatre-like embayment are separated by a concealed interval of about 30 feet (9 m.), from the red and dark green shales of division 1, exposed in the long rock cuttings on the railway line.

The strata of division 3, consisting chiefly of dark shales, outcrop along the shores of the river for a distance of about 200 feet (60 m.), or as far down the river as the place where the river channel commences to narrow. At this place are outcrops of light coloured, quartzose sandstone interbedded with shales. The strata dip southward at an angle of 35°. These ledges mark the position of the assumed northern boundary of division 4. The sandstone, in heavy beds with interbeds of dark shale, outcrops down stream for a further space of about 200 feet (60 m.). Beyond this, exposures cease and no more outcrops occur for a long distance downstream. The sandstones are lithologically ve y similar to the sandstones

associated with the limestone conglomerate at Bic and resemble the sandstones and associated conglomerate of other localities.

The sandstones of division 4, are, apparently, conformable with the shales of division 3. If, as the single fossil species seems to indicate, the shales are of Lévis age, then the quartzites are also of this age. The strata of divisions 2 and 1 seem to be conformable, though locally separated by a break. The fossils recovered from division 1 indicate that the strata are not older than Upper Cambrian: they may be of approximately the same age as divisions 2 and 4.

The structures exhibited by the strata of division 2 in the cliff face below the falls—the gradual change in attitude from an inclined one to a nearly horizontal, plicated one, and the fact that the zone of plications does not bear any evident relation to the plane of the thrust fault—indicate that the measures lie in a deformed, overturned anticlinal fold, which during the process of folding was plicated at the apex. If this be so, then, as the existence of the thrust fault and the uniform direction of the dip of the strata both above and below the fault indicate, a thrust fault developed after the fold was overturned, whereby the upper portion of the recumbent fold was thrust forward over the overturned, lower limb so that stratigraphically lower measures came to lie on stratigraphically higher measures. This general conclusion apparently is supported by the somewhat meager fossiliferous evidence so far obtained. If the above suppositions are correct, it follows that the quartzites of division 4, are the youngest strata exposed in the section and not, as at one time thought, the oldest. On the above general grounds, the true order of succession of the strata of the section in descending order is,—

Division 4, grey quartzose sandstones with interbedded dark grey shales.

Division 3, dark grey shales.

A section of strata unrepresented because of the presence of thrust fault.

Division 1, red ,green and dark shales, with beds of limestone conglomerate, limestone and sandstone.

Division 2, interbedded dark, grey shales and light coloured sandstones.

BIBLIOGRAPHY.

1. Bailey, L. W., and McInnes, W.; Geol. Surv. Can., Annual Report, vol. 5, 1890-91, part M.
2. Dresser, J. A......Geol. Surv. Can., Map 34 A.
3. Ells, R. W........Geol. Surv. Can., Annual Report, vol. 3, 1887-88, part K.
4. Logan, W. E......Geol. Surv. Can., Geology of Canada 1863.
5. Logan, W. E......Geol. Surv. Can., Report of Progress, 1863-66.
6. Richardson, J......Geol. Surv. Can., Report of Progress, 1866-69.

RIVIÈRE DU LOUP.

THE POST–GLACIAL MARINE SUBMERGENCE.

(J. W. GOLDTHWAIT.)

At Rivière du Loup terraces and benches at various levels on the slaty hillsides offer little that is reliable as an index to the extent of marine submergence. In the southwest part of the town, however, two rather delicate gravelly beaches may be traced through the fields, at a height of 372 feet. Inasmuch as this measurement at Rivière du Loup harmonizes with those at other places along the coast, lying on the same inclined plane, it seems safe to accept it as the upper limit of submergence. This agrees perfectly with the determination made by Baron De Geeri n 1892* Just beyond the car shops a ditch beside the Intercolonial railway showed in August 1912, a very fine cross section of a shell bed 340 feet above sea level. This is not only the highest occurrence of Pleistocene marine shells east of Quebec, but one of the rare instances of marine shells close to the upper limit of submergence. The unusually large size of the *Saxicava arctica* and the profusion of them in these old tidal flats

*G. De Geer: On Pleistocene changes of level in eastern North America. Boston Society of Natural History, Proc.; vol. 25, 1892, pp. 454--477; and American Geologist, vol. 11, 1893, pp. 22--24.

at the mouth of the Riviére du Loup, indicates that conditions for life here were exceptionally favourable. Several other types of shells occur in the deposit, but fully 95 per cent are *Saxicava*. Heavy gravels of this delta, but barren of fossils, are exposed across the river, not far from the railway station.

ANNOTATED GUIDE.

RIVIÈRE DU LOUP TO BIC.

(G. A. YOUNG.)

Miles and Kilometres.

0 m.
0 km.

Rivière du Loup—Alt. 315 ft. (96·m.). From Rivière du Loup to Bic, the St. Lawrence river is bordered by a wide zone of the same general succession of strata traversed by the railway from Quebec eastward. The measures consist largely of red, green, black, and grey slates with bands, mostly of limited extent, of quartzose sandstone. With these occur beds of sandstone and of conglomerate bearing limestone pebbles and boulders. The strata in general strike parallel with the St. Lawrence shore but are everywhere much folded and contorted; overturned folds and faults occur at many points. The strata in general have been usually regarded as being of Cambrian age. The measures in the neighbourhood of the coast were considered by Logan to underlie the Sillery formation. With the exception of the fossils recovered from the limestone fragments in the conglomerates, the only fossil recorded from the strata of the district is *Obolella pretiosa*. The zone of these measures extends inland at Rivière du Loup for about 30 miles (50 km.). Farther east, the zone decreases in width and at Bic it is only about 7 miles (11 km.) broad. These Cambrian or Ordovician measures are bounded on the south by Silurian strata consisting largely of intricately folded dark slates.

Leaving Rivière du Loup the Intercolonial railway for a number of miles, passes along or near the steep drop leading to the low lying

Miles and Kilometres.

land bordering the St. Lawrence. To the southward the country rises gradually inland in a broken, rolling fashion.

27 m. **Trois Pistoles Station**—Alt. 112 ft. (34·1m.).
43·5 km. On the shore at Trois Pistoles, in a measured section of 700 feet (213 m.) of strata, 150 feet (47·7 m.) consist of grey calcareous sandstone and conglomerate. The conglomerate occurs in nine beds 2 to 16 feet (0·3 to 4·9 m.) thick. The rounded masses in the conglomerate are chiefly of limestone weighing from a pound to a ton (1,000 kilos).

35·6 m. **St. Simon Station**—Alt. 296 ft. (90·2 m.).
57·3 km. The railway passes through a succession of comparatively wide valleys whose bounding ridges gradually increase in height. These ridges are presumably largely formed of resistant quartzose sandstone. The bounding ridges on the north, though parallel with one another, slightly overlap. It is probable that this feature is indirectly due to the faulting of the resistant bands of quartzose sandstone.

Approaching St. Fabien banded red and green, and dark slates are exposed in rock cuttings. The strata are crumpled and contorted.

45·5 m. **St. Fabien Station**—Alt. 445 ft. (135·6m.).
73·2 km. From St. Fabien to Bic, high abrupt ridges rise to the northeast of the valley traversed by the railway. Approaching Bic, these ridges as seen from the railway, possess very steep faces on their seaward sides while on the landward sides, the slopes are more gentle. The hill forms apparently conform in outline to the general southerly dip of the strata.

At intervals along the railway, are exposures of slates and quartzose sandstone.

54·8 m. **Bic**—Alt. 82 ft. (25 m.).
88·2 km.

BIC.*

(G. A. YOUNG.)

INTRODUCTION.

Bic, like Rivière du Loup, is situated within the long extended zone of the Quebec group, which borders the south side of the St. Lawrence from opposite Quebec city nearly to the extremity of Gaspe peninsula. A certain amount of prominence in geological literature has been given Bic and other neighbouring localities because of the occurrence of conglomeratic strata containing, in places, fossiliferous limestone pebbles. Somewhat similar conglomerate beds occur at various horizons in the Quebec group and at intervals throughout the whole extent of the group from Lévis northeastward. These occurrences of conglomerates differ amongst themselves in that in some cases the fossils of the pebbles may represent an assemblage of distinct faunas ranging in age from Lower Ordovician to Lower Cambrian; or the fossils present may all belong to one general fauna, as in the case of the conglomerates at Bic where fossils of Lower Cambrian age only, have been recovered.

One general characteristic is common to all the known fossiliferous conglomerate horizons,—the original source of the fossiliferous strata has not been established and, though the present borders of the Laurentian Pre-Cambrian area lies so close, yet pebbles or boulders of typical Laurentian rocks are exceedingly rare if not in most cases entirely absent from the conglomerates.

The following statements regarding the fauna occurring in the conglomerate in the vicinity of Bic have been prepared by Charles D. Walcott.

'The fauna occurring in the boulders and limestone at Bic harbour is that found in the later deposits of the Lower Cambrian rocks both in Newfoundland and the St. Lawrence valley, also in some of the older deposits of the Lower Cambrian. It is marked by the presence of *Olenellus thompsoni*, which occurs in the later deposits

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*See Map—Bic.

both on the Straits of Belle Isle and in the Lake Champlain valley. The presence of *Hyolithellus micans*, *Microdiscus lobatus*, and *M. speciosus* indicates that there is also present a portion of a somewhat older fauna than that occurring with *Olenellus thompsoni.*'

'The origin of the boulders containing the Olenellus fauna is unknown. There is a marked lithological and palæontological similarity between them and the Lower Cambrian limestone of Topsail head and Conception bay, Newfoundland, that points to similar conditions of sedimentation and life, and I found the head of an Olenellus on the Island of Orleans that is of the type of *O.* (*M.*) *bröggeri* of Newfoundland. It is quite possible that the deposits from which the conglomerates were derived extended around the Newfoundland coast, to the west and north, and thence along the margin of the Pre-Cambrian land, southwest, toward the Adirondack mountains of New York, and that the disturbances toward the close of the Cambrian period, in the St. Lawrence valley, resulted in the uplifting of the Lower Cambrian strata and its denudation and breaking up during Upper Cambrian and Lower Ordovician time.'

'From Bic harbour, Trois Pistoles, and St. Simon the following species have been found in the conglomerate limestone:—

Lingulella caelata	Agnostus sp.?
Iphidea bella,	Microdiscus lobatus,
Kutorgina cingulata,	Microdiscus speciosus,
Obolella crassa,	Olenellus thompsoni,
Obolella circe,	Olenoides marcoui,
Obolella gemma,	Olenoides levis,
Orthis, 2 n. sp.,	Ptychoparia adamsi,
Platyceras primaevum,	Ptychoparia teucer,
Scenella retusa,	Ptychoparia (?) trilineata
Stenotheca rugosa,	Ptychoparia, sp. undt.
Hyolithes americanus,	Agraulos strenuus,
Hyolithes communis,	Protypus senectus,
Hyolithes princeps,	Protypus senectus, var. parvulus,
Hyolithellus micans.	

'The above fauna proves clearly that there was a large and varied Lower Cambrian fauna in the limestone from which the boulders of the Bic conglomerates were derived,

and that the fauna is essentially the same as that of the Lake Champlain and Upper Hudson river area in eastern New York.'

The conglomerates which are displayed so prominenty at Bic and for some distance to the southwest and north-east, are confined to a comparatively narrow belt along the coast. They occur in conspicuous ridges surrounded or alternating with low-lying areas occupied by shales and slates. The prominence thus given to the conglomerates, their interesting features and their situation on the coast, has naturally directed the attention of geologists to them, but in spite of this, comparatively little detailed information has been recorded.

Since the fossils found in the conglomerates occur in pebbles, it is evident that the fossiliferous evidence fixes only the lower limit of the possible range of age of the beds; the conglomerate cannot be older than the age of the fauna represented in the pebbles and boulders. Consequently any attempt to more definitely determine the age of the conglomerates must be based on other lines of evidence.

James Richardson in two early reports [**2**, pp. 126–7, p. 149; **3**, p. 130] assigns the Bic conglomerates to a position stratigraphically beneath the Sillery. In a much later report, L. W. Bailey and W. McInnes [**1**] assign the Bic conglomerates to a horizon in the upper part of the Sillery (Cambrian). It is stated [**1**, p. 22] that, in general, the conglomerates are displayed along synclinal or anticlinal axes. The general succession of the strata is stated to be as follows arranged in descending order,—

(a) Fine grained sandstone or quartzite, grading downwards into,
(b) Conglomerate and sandstone grading downwards into,
(c) Comparatively coarse conglomerate, resting on,
(d) Red, green and purple slates.

This general arrangement, it is stated, obtains at Bic, where besides the main band of conglomerate, other smaller bands occur.

DETAILED DESCRIPTION.

In the limited area bordering Bic river and the eastern end cf Bic harbour, represented on the accompanying

geological sketch map, the strata consist of zones or bands of quartzose sandstone or quartzite and conglomerate alternating with bands of shale or slate. The strata, in a general way, strike east and west and are traversed by a series of faults striking to the west of north. The fault planes are presumably vertical or nearly so and in the cases of all the faults observed the strata on the western side of the fault plane, relatively to the strata on the eastern side of the fault, are displaced towards the north. Besides these more easily detected faults that strike in a northerly direction, there are also present others striking in an east and west direction.

The strata of the zone of quartzite and conglomerate traversed by Bic river, south of Bic harbour, is, in its northern portion folded into an open synclinal form, and the quartzites and conglomerates therefore overlie the dark shales exposed along the railway. Possibly the two bands of quartzite on the northern side of the estuary of Bic river, represent tightly compressed folds of the same quartzite horizon, but the evidence is not complete in this respect. In the case of the broad belt of quartzite and conglomerate south of the railway, the southern portion, south of the synclinal axis referred to, apparently is folded into an anticline, and along the southern border of the area, the quartzites dip steeply beneath dark shales interbedded with light coloured, fine grained sandstones.

Fossils occur in the conglomerates at Bic at a number of points. One of the more readily accessible of these is a short distance west of Bic station and to the south of the railway. The first conglomerate band south of the railway, at this point, contains many fossiliferous limestone pebbles, in which the most common fossils are *Olenellus thompsoni*, *Protypus senectus* and *Microdiscus*.

The general geological structure and the nature of the stratigraphical divisions may be observed if the road leading southward from Bic station is traversed as far as the crossing of Bic river, and if also the road leading northwestward along the eastern side of Bic harbour is followed to its ending.

A very short distance west of Bic station and immediately south of the railway, there rises a partly wooded ridge extending for some distance west of Bic but ending abruptly on the east just south of Bic station. This ridge is formed

A1.

Geological Survey, Canada

Bic

Feet
500 0 500 1000 1500 2000
Metres
100 0 200 400 600

(Scale of map is approximate)

of alternating beds of coarse and fine quartzite, and conglomerate either disposed vertically or dipping to the south. At the foot of the northern slope, the quartzite and conglomerate are interbedded with black slate, while along the railway line the strata are entirely composed of black slates. The interbedding of the quartzites and slates along the boundary of the two divisions and the absence of any appearances of structural unconformity indicate that the slate series and the quartzite series are conformable, while the uniform southerly direction of dip in the eastern part of the ridge and an open synclinal fold developed to the south indicate that the quartzite series overlies the black slate division.

The road leading southward from Bic station ascends a gently rising slope and passes a few hundred feet to the east of the abrupt end of the quartzite ridge. Along the roadside are exposed nearly vertical beds, striking westward, of purple weathering dark shales; these shales at the southern end of the exposure contain thin beds (1 to 6 inches; 2 cm. to 15 cm.) of fine-grained sandstone and these dip southward at an angle of 60°. The slates strike directly towards the quartzite ledges exposed along the east slope of the hill and, evidently, must be separated from them by a fault plane.

No further outcrops occur along the road for some distance. As the road is followed southward, the outcropping ledges of white quartzite to the west, may be seen to approach closer and closer to the road. Just beyond where a branch road leads to the west and close to the Bic river, an exposure of dark weathering, greenish slate occurs on the roadside while, just beyond at the turn of the road, are outcrops of quartzite and conglomerate. These two exposures are believed to lie on opposite sides of the above mentioned fault plane. In the general area to the east of the fault plane,—along the river, over the ridge on the southern side of the river, and elsewhere, only dark slates and the associated thin beds of sandstone are exposed. West of the fault plane the strata are almost entirely light coloured quartzites and conglomerates.

At the bridge over the river the quartzite beds are displayed in the crown of an anticline. On the river below the bridge, the quartzites dip southerly at angles of 20° to 30°, while those above the bridge dip at low angles to

the north. Both above and below the bridge dark shaly measures are interbedded with the quartzites and outcrop from beneath them, and it is assumed that these beds mark the summit of the shale division underlying the quartzites. To the south on the southern limb of the anticline, the quartzites and conglomerates dip at high angles to the south or are vertical. Along the southern boundary of the quartzite area, the strata dip southward at angles of from 60° to 80°, and disappear beneath an overlying series of dark shales with interbedded sandstones. To the north of the river, the strata on the north limb of the anticline dip at low angles to the north, but just north of the road leading west, the measures are traversed by a synclinal axis and the direction of dip rom this point to the north brow of the hill is to the south.

The dark slates on the east side of the major fault noted above, are exposed along Bic river as far down as the railway crossing. A small outcrop of these rocks occurs in front of the parish church. The slates everywhere dip to the south at high angles. These beds thus appear to form the northern limb of a syncline, though it is possible they form the limb of an overturned anticline. If the shales respectively to the east and west of the major fault belong to the same horizon, the more natural assumption, and this is the one adopted, would be that the strata lie in the northern limb of a syncline.

From the square in front of the parish church, looking northward across the railway and beyond an open field, a low ridge of light coloured rock may be seen separated by a low-lying interval from a much higher ridge to the north. Both ridges strike in an east-west direction and are formed of quartzites and conglomerates. The intervening, low ground is underlain by dark slates.

No exposures occur along the road leading northward from the church to the railway nor do any occur for some distance along the shore road skirting the eastern side of Bic harbour. At the falls on Bic river at the railway bridge, dark shales with thin sandstone beds dip in a southerly direction at an angle of 55°. A ten-foot bed of limestone conglomerate forms the projecting rib of rock which is the immediate cause of the falls. Along the shore road, to the north of the crossing of Bic river, the first exposures are of conglomerate. The conglomerate as seen on a weathered surface, consists of a mass of rounded

and angular, light coloured fragments lying with very little evidence of bedding, in a dark matrix of the nature of a coarse, quartz sandstone or quartzite. The embedded fragments vary in size from very small up to one foot or more in diameter, and when broken out from the matrix may be seen to possess smooth, rounded, waterworn outlines. As may be noticed in this and other exposures, certain beds of the conglomerate are characterized by the uniformly small size of the contained fragments, others by the relatively large size of the fragments. The fragments consist chiefly of limestone, the most abundant variety being a dense, bluish-grey type. Pebbles and boulders of sandstone, quartzite, quartz, limestone conglomerate, sandstone conglomerate, etc., are also present.

Towards the west end of the exposure of conglomerate, a small body of dark shale is exposed on the roadside in contact with the conglomerate. The same dark shale or slate is exposed westward along the shore. Apparently this locality is at the contact of the conglomerate with the large body of shales extending to the south. If it be true, as has been assumed, that the shales lie on the northern limb of a syncline, then the conglomerate and quartzite band to the north belongs to a horizon lower than that of the body of similar strata forming the ridge southwest of Bic station.

Westward from the exposure of conglomerate, the highway approximately follows the boundary between the conglomerate and quartzite on the north, and the shales on the south. The line of contact between the two divisions is very irregular in detail probably as a result of deformation that took place during the folding and subsequent faulting of the measures when, doubtless, the shales as a whole acted as a relatively plastic body and the conglomerates and quartzites as a brittle mass. Along this portion of the road, the quartzite beds associated with the conglomerates, are exposed. The quartzite composes the bulk of the formation. It is usually fine grained but in places is sufficiently coarse to be termed a grit and is composed almost exclusively of rounded quartz grains in a silicious matrix.

No rocks outcrop along the road where, after passing through a cut in conglomerate, it bends to the eastward along the edge of the low ridge. The quartzites and conglomerates in this ridge are vertical or dip steeply to the

south. It may be assumed therefore, that these measures also lie in the northern limb of a syncline.

Along the road where after following a northerly course for a short distance, it again turns and strikes to the west, several exposures of conglomerate occur to the south of the road, while on the road and in the fields on the north side are outcrops of dark shale. A short distance farther on in a low, small knoll, the conglomerate and the slaty rocks are displayed in contact with one another, the strata dipping steeply to the south. The road, apparently, follows the northern boundary of the belt of conglomerates and quartzites.

At the place close to the shore where the road bends to the north, several hummocks of conglomerate occur on the east side of the road; their presence apparently indicates the existence of a north-south fault lying just east of the exposures. Northward, along the road, a single exposure of dark shale occurs before the ending of the road at the pier which apparently is situated almost directly on the course of the above mentioned fault, the presence of which is indicated in the strata exposed at low water along the eastern side of the pier.

At the beginning of the pier, conglomerate and quartzite are exposed to the east. The strata are much fractured and are veined with calcite. These measures form the prominent ridge which fronts on the coast and extends for several miles to the east. Similar strata are exposed on the island on whose side the pier is built, and the general characters of the conglomerate and quartzite are excellently displayed in large exposures.

On the island the strata dip towards the north at comparatively low angles. It is inferred that the strata of the ridge along the coast occur in the form of an anticline probably deformed by faulting, and that this band of conglomerate and quartzite dips beneath the first zone of dark slates to the south, and that these in turn dip beneath the strata of the succeeding band of quartzite and conglomerate.

The general inferred succession of the strata displayed in the immediate vicinity of Bic is as follows, arranged in descending order,—

(a) Dark slates with interbedded sandstone.
(b) Quartzite with interbedded conglomerate.

(c) Dark slates, in places weathering with a purplish colour; occasional relatively thin beds of limestone conglomerate.
(d) Interbedded quartzites and conglomerate.
(e) Dark slate.
(f) Conglomerate and quartzite.

The total thickness of the series displayed must be considerable, perhaps in the neighbourhood of 3,500 feet (1,066 m.), but no reliable estimate of the thickness has been formed. Regarding the age of the strata it may be stated that it cannot be older than Lower Cambrian since the fauna of the limestone pebbles in the conglomerates is of this age. Presumably the series is at least as young as Middle Cambrian and possibly still younger. It is noteworthy that lithologically the quartzites are identical with the quartzite or quartzose sandstone displayed at Rivière du Loup below High Falls. The somewhat scanty fossiliferous evidence obtained at Rivière du Loup indicates that there the quartzite is of Lower Ordovician age; possibly the strata at Bic are of about the same age.

BIBLIOGRAPHY.

1. Bailey, L. W., and McInnes, W. L. Geol. Surv. Can. Annual Report, vol. 5, 1890–91, part M.
2. Richardson, J.....Geol. Surv. Can., Report of Progress 1858.
3. Richardson J......Geol. Surv. Can., Report of Progress, 1866–69.

BIC: THE POST-GLACIAL MARINE SUBMERGENCE.

(J. W. Goldthwait.)

Just to the west of Bic railway station one may see a record of glaciation towards the north,—according to Chalmers' interpretation—by the ice from the Appalachian highlands. A well formed roche moutonnée close beside the track is severely scrubbed on the south side and torn and roughened on the north. Among the ledges of limestone and conglomerate which outcrop in the hills south

of the railway, well formed pocket beaches may be seen. Unlike the prevailing slate of the St. Lawrence plain, which splinters and flakes in a most unfavourable way for beach construction, the limestone supplied the waves with an abundance of good pebble making material. Here, therefore, is one of the most satisfactory places on the whole coast of the St. Lawrence to determine the height to which the sea has washed the surface. A mile or two southeast of the station, the upper marine limit is very distinctly marked by a set of gravelly beaches

Micmac bluff and terrace at Bic, Quebec.

that stop abruptly at 311 feet (94·8 m.). On ledges slightly above this level, the thickly scattered joint fragments of limestone show no sign whatever of rounding and assorting. No marine fossils have been discovered in these highest beaches; in fact, discoveries of shells at the extreme upper reach of submergence are rarely made. Fossils of sub-arctic species may be collected, however, from the deeper water clays at 120 feet (36·5 m.) two miles east of the station on the road to Hattie bay. On the

north side of the railway the village of Bic extends out to the brink of the old Micmac sea-cliff, which reappears here with all its characteristic freshness and strength. The great length of the Micmac stage is the more evident when one compares the great sea cliff with the low bank and marshy beach at the modern high tide mark. The last twenty feet of the whole 311 feet (94·8 m.) elevation of the coast at Bic seems to have been accomplished only after centuries of stability or of slow coastal subsidence; and judging by the ineffectiveness of the modern waves this renewed uplift may still be going on.

ANNOTATED GUIDE.

BIC TO MATAPEDIA JUNCTION.

(G. A. Young.)

Miles and Kilometres.
0 m.
0 km.

Bic—Alt. 82 ft. (25 m.). From Bic to Matapedia Junction the Intercolonial railway for about 100 miles (160 km.) or as far as Little Metis, parallels the St. Lawrence river either passing close to the shore or inland at a distance of several miles. Throughout this distance the railway traverses a portion of the belt of 'Cambrian' strata that borders the St. Lawrence on the south side from Quebec city eastwards. As in the sections between Quebec and Bic, the strata are largely red, green and black slates with bands of sandstones, and local developments of quartzose sandstones and conglomerates containing fragments of fossiliferous limestone. The measures in general strike parallel with the St. Lawrence, but are closely folded and much faulted. The 'Cambrian' strata of this belt are bounded on the south by a wide area of Silurian limestones.

At Little Metis the course of the railway turns inland, runs in an easterly direction across the full width of the belt of 'Cambrian' measures, and entering the Silurian and Devonian area of the Shickshock mountains, runs first

Miles and Kilometres.

southeast and then south across the axis of the mountains by way of the Matapedia valley. The Silurian and Devonian strata of the Shickshock mountains occupy the greater part of the Gaspe peninsula and in Canada, extend southwestward from the eastern extremity of Gaspe peninsula to beyond the Temiscouata river, a distance of about 250 miles (400 km.). In age the measures range from Niagara or younger to late Devonian, and apparently form a conformable group. The Silurian measures are largely dark grey slates and calcareous slates, but limestones occur at various horizons, more especially towards the top of the series. The lower Devonian measures are largely slates, calcareous slates, and limestones. The upper Devonian strata are dark grey shales and sandstones containing, in places, an abundance of plant remains. The strata in the extreme eastern portion of Gaspe peninsula strike in general, somewhat south of east; towards the centre of the peninsula the general strike is east and west; farther west, in the Matapedia valley the general strike is about south-southwest; while still farther west, the general strike is southwest. Over a considerable portion of the peninsula the measures lie in broad open folds, but in many parts and over large districts the strata are closely folded and are traversed by numerous dislocations.

After leaving Bic, the railway approaches and closely follows the shore where, as near Sacré Coeur, dark slates outcrop with low angles of dip.

6·3 m. **Sacré Coeur Station**—Alt. 20 ft. (6 m.).
10·1 km. 'The view of the great Micmac cliff and terrace near Sacré Coeur is very instructive. On the left hand side of the track is the steep, straight wave-cut bluff, whose base is approximately 20 feet (6 m.) above mean tide. Slate outcropping along the face of it shows that the waves at this stage cut back with power and persistence for a long period of time. On the other side the gravelly wave swept terrace,

Miles and Kilometres.

now well out of reach of the sea, stretches forward to the water's edge, and merges almost imperceptibly with the tide-covered flats which run out as far as the eye can see. These mud flats are in many places so thin that the wave-bevelled edges of the layers of slate show through them, testifying to the complete planation of the Micmac shelf by the sea at the time when it was advancing against the cliffs. The indefinite, expressionless beach which lies along the line of modern storm waves, half concealed by salt marsh grass, is insignificant as a record of wave rock, in comparison with the great sea-cliff that marks the twenty-foot stage. These vast mud flats, which follow the south shore all the way to Quebec, are plainly the still submerged outer portion of the Micmac terrace and not the product of wave action at the present level save for the soft muddy sediment which scarcely conceals the rock surface, and the ice-rafted boulders which lie scattered abundantly over the shallow water zone. The upper marine beaches, also, which lie out of sight of the railway, on the upland above the old sea-cliff, are comparatively indistinct. The highest one stands at 294 feet (89·6 m.). Three-quarters of a mile beyond Sacré Coeur, the Micmac sea-cliff attains its greatest strength, rising precipitously over a hundred feet above the shelf on which the railway runs. It is important to note that through this whole district the altitude of this terrace is constant, and continues without change all the way to Quebec." (Note supplied by J. W. Goldthwait.)

Approaching Rimouski, cuttings in dark slates occur along the railway.

10·5 m.
16·9 km. **Rimouski Station**—Alt. 54 ft. (16·5 m.). Beyond Rimouski, the railway swings away from the shore and traverses a low, gently rolling country bounded inland, by a series of parallel ridges. Approaching Ste. Flavie, the country is more broken, the ridges inland are

Miles and Kilometres.

higher and still higher ones are visible in the distance.

28·5 m.
45·8 km.

Ste Flavie Station—Alt. 266 ft. (81 m.). "At Ste. Flavie, the station stands within a few hundred yards of the upper marine limit, which is marked by an obscure sandy beach in the house lots on a back street southeast of the track. It is 272 feet (82·9 m.) above sea level. Beyond, on higher slopes the form and composition of the ground indicate that no submergence has taken place. Between the 272-foot beach and the shore of the St. Lawrence are a number of gravelly beaches. Three miles beyond St. Flavie, the valley of Grand Metis river is crossed. Looking up the valley, high ridges are visible. The flat ground on both sides of the river, here, is the top of an extensive delta, built during the emergence of the coast from the sea. Its altitude, about 260 feet (79·2 m.) above sea level, corresponds closely with the altitude of the highest beach at Ste. Flavie. At Priceville, a large lumber town at the falls of the Grand Metis river, within sight of the railway bridge, the delta gravels contain myriads of mussel shells, at an altitude of about 175 feet (53·3 m.)." (Note supplied by J. W. Goldthwait.)

Beyond the crossing of Grand Metis river, rock cuttings in dark slates occur along the railway which, gradually rising, passes along the edge of a steep drop to the low foreland bordering the St. Lawrence. From this section is obtained a last view of the Laurentian highlands on the north side of the St. Lawrence, 30 miles (50 km.) away.

The railroad finally turns to the east and entering the valley of Little Metis river crosses the band of Sillery and associated strata which has continued uninterruptedly from Lévis, 190 miles (300 km.) to the southwest and which extends for 165 miles (265 km.) farther to the northeast, to the extremity of Gaspe peninsula. In the extension of this band to the northeast, graptolite-bearing shales of Utica age (Upper Ordovician) are infolded with the older measures.

Miles and
Kilometres.

38·6 m. **Little Metis Station**—Alt. 569 ft. (173·4 m.).
62·1 km. Little Metis station is high on the side of the valley of Little Metis river which the railway follows upwards for a few miles passing through many rock cuttings in red and dark slates, and sandstones. The strata in some of the rock cuttings are highly contorted.

Leaving the Little Metis valley, the railroad continues to ascend through a rough, broken country.

42·5 m. **Kempt Station**—Alt. 688 ft. (209·7 m.).
68·4 km. Beyond Kempt the railway passes through rock cuttings in red and black slates. The railroad then follows up the valley of a small stream with rock walls of dark slates.

50·5 m. **St. Moise Station**—Alt. 540 ft. (195 m.).
81·3 km. In the neighbourhood of St. Moise an extensive view is afforded to the northeast over a low, broken country with one rather high hill nearby. Rock cuts in red and black slates occur along the railway which at a point several miles east of St. Moise, passes over a low summit, altitude 771 ft. (235 m.) and drops to the shores of a small lake draining eastward to Lake Matapedia. A short distance beyond this small lake, the last rock cut in the dark "Cambrian" slates is passed and the railway enters a comparatively level area underlain by nearly flat-lying Silurian measures. The level area is bounded on the southwest by the high hills of the Shickshock or Notre Dame mountains visible from the railway. The Silurian strata unconformably overlie the "Cambrian". The lowest beds are white and pinkish sandstones with a thickness of about 60 feet (18 m.). These are overlain by dark grey fossiliferous limestone probably of Niagara age.

57·9 m. **Sayabec Station**—Alt. 578 ft. (176·2 m.).
93·2 km. Sayabec is situated about a mile south of the head of Lake Matapedia. A few miles past Sayabec the railroad approaches close to the shore of the lake. Nearly horizontal Silurian strata outcrop along the southwestern shores

Miles and Kilometres.

but on the opposite side, towards the head of the lake, folded "Cambrian" strata occur while towards the foot of the lake, metamorphosed rocks possibly of Pre-Cambrian age, are present.

Towards the foot of the lake and for the first few miles in the rather broad valley of Matapedia river, there are no rock exposures.

72·9 m. 115·7 km. **Amqui Station**—Alt. 532 ft. (162·1 m.). Beyond Amqui, rock cuts occur along the railway in dark slates with occasional beds of fine sandstone and thin beds of limestone. The measures in most places lie with low angles of dip but in places are highly inclined.

Approaching Causapscal the railroad crosses the river to the east side of the hitherto broad valley but which in this neighbourhood contracts.

86·3 m. 138·9 km. **Causapscal Station**—Alt. 454 ft. (138·4 m.). Beyond Causapscal, the river valley again broadens and cuts across a six-mile wide belt of greyish and yellowish sandstones and arenaceous shales. These measures represent the Gaspe sandstone series and are presumably of late Devonian age. The strata are highly inclined in the form of a synclinal fold. They terminate a few miles to the west of the river, while in an easterly direction they extend continuously for 150 miles (240 km.) to the extremity of Gaspe peninsula. At several places in the interior of Gaspe, the Devonian sandstone series rests unconformably upon Silurian measures. On the Matapedia, it was supposed by Logan, that the Silurian and Devonian were conformable.

92·8 m. 149·4 km. **Beau Rivage Station**—Alt. 366 ft. (111·6 m.). Beyond Beau Rivage, the Silurian area is again entered and numerous rock cuts in the highly inclined, dark grey calcareous slates occur along the railway to Matapedia Junction, where the Matapedia joins the Restigouche river.

Below Beau Rivage, the river valley gradually contracts and the bordering hills rise to higher heights. The various tributaries of the Matapedia river irrespective of their sizes, occupy

Miles and Kilometres.

deep valleys joining the main valley at grade. The Matapedia valley also enters the wider, Restigouche valley at grade. The wide and deep Restigouche valley is the inland continuation of the broad valley of Chaleur bay.

120·9.m 194·6 km. **Matapedia Junction**—Alt. 53 ft. (16·2 m.).

DALHOUSIE AND THE GASPE PENINSULA.*

(John M. Clarke.)

INTRODUCTION.

The general region dealt with in the following account embraces the head of the Bay Chaleur region and the great peninsula of Gaspe. The Bay Chaleur is an east-west arm of the Gulf of St. Lawrence, about 100 miles (160 km.) in length, and constitutes the marine boundary between the provinces of New Brunswick on the south and Quebec on the north. It was discovered and named by Jacques Cartier in 1534. The chief affluent of the bay is the Restigouche river, in its lower reaches a continuation of the boundary line between the provinces and also the site of large private salmon-fishing preserves. The mouth of the Restigouche river and the head of the bay are conventionally located at Dalhousie, N. B., on the south and Maguasha Point, P.Q., on the north, and here the width of the bay is about 3 miles (5·4 km.). Campbellton lies on the Restigouche river, 15 miles (27 km.) above Dalhousie. Here the river has narrowed to about ¾ miles (1·3 km.). Opposite Campbellton on the north (Quebec) shore is the Reservation and Mission of the Micmac Indians at Restigouche.

The Devonian beds and their volcanic intrusives about Dalhousie were early discussed by Hind, Bailey and J. W. Dawson, and the official geological maps of the region were compiled by Ells, by whom also the geological relations of these rocks were discussed at some length. The first identification of the fossils was by Billings; subsequently the fossil corals were carefully studied by Lambe and more recently the entire marine Devonian fauna and stratigraphy has

*See Maps—Head of Chaleur Bay, and, Eastern Part of Gaspe.

been elaborated in detail by Clarke. The Devonian rocks at and near Campbellton are similarly intruded and altered by volcanics. They became of general interest through the discovery by Ells and Foord, some thirty years ago, of fish and plant remains, and it is to these fossils that geologic interest at this point has been chiefly directed.

The Gaspe Peninsula, bounded on the south by the Bay Chaleur, on the north by the St. Lawrence river, and fronting east on the Gulf of St. Lawrence, covers an area of about 11,000 square miles (28,600 sq. km.). It is larger than the Kingdom of Saxony and twice the size of the State of Massachusetts. The interior of this great peninsula is a rolling, heavily timbered wilderness, only the coast region, for a maximum width of 10 miles (18 km.), having been opened to settlement. Its geological structure is best exposed in the sea sections, some of which are very striking. The peninsula constitutes the northernmost and terminal region of the Appalachian Mountain system and here the folded ridges take on their most pronounced sigmoid curvature, bending from the SW.-NE. direction which is normal to them at the south, through an arc at the north which ends at Cape Gaspe in a NW.-SE. curve. Pertaining thus to the Appalachian system, the Gaspe region is quite exclusively an area of Palæozoic rocks. The Notre Dame or Shickshock* mountains, which are the greatest elevations of the peninsula, (3,000- 4000 feet or 900-1,200 m.), lie at the north and carry areas of mica schists, jaspilites and epidotised gneiss, evidently forming a basement to the Cambrian shales, but the Pre-Cambrian age of none of these has been demonstrated. Peridotites and serpentines are also of extensive occurrence in these mountains. Generally speaking, Gaspe is a region of regular appalachian folds and extensive overthrusts of the older Palæozoic strata, the extraordinary displacements in which have been largely concealed by a mantle of later (Devono-Carboniferous) nearly horizontal sandstones and conglomerates.

The geology of Gaspe was first studied by Sir William Logan in 1845. It was the first field he entered after his organization of the Geological Survey of Canada, and his reports upon the region are still fundamental. Later

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* Notre Dame is Champlain's name for these mountains; Shickshock, the Micmac Indian name.

the region was entered by Bell, and particularly by Ells and Low, who made a resurvey of the peninsula in 1878-1882 and issued an entire series of maps of the area. Clarke has more recently studied the coastal region with special reference to the composition and correlations of its faunas and stratigraphy.

Along the shores of the peninsula are outcrops of the Cambro-Ordovician, Silurian, Devonian and Devono-Carboniferous (Bonaventure) formations. Not all of these formations have been deposited in one basin. The evidence is very clear that the earliest endroits were the broad marine channels of an ancient St. Lawrence trough having the SW.-NE. trend of the orogenic axes of to-day, with continental land at the north (the Labrador crystalline shield) and at the south, for the most part outside the boundaries of the present land. In some degree the bays of to-day (e.g. Gaspe bay, Mal bay) running in from the coast of the Gulf lie in ancient synclines which date back to the later stages of the Devonian. Sea erosion, however, has been so efficient that the lower reaches of the St. Lawrence river which washes the north shore of the peninsula are bounded by a wave cut rock platform in places 8 miles (14·4 km.) in width, lying at a depth of not more than 300 feet (90 m.) below the present water level. Where the sigmoid curve of the Appalachian ridges is most pronounced, that is, in the little peninsula of the Forillon at the north between the St. Lawrence river and Gaspe bay, the outermost eastern tip of the Appalachian system is to be found in the fishing ground known as the "American Bank", which, submerged a few fathoms, lies 10 miles (18 km.) out to sea from the tip of Cape Gaspe, in the SE. course of the mountain folds. This fact has been determined by the dredged rocks from this bank.

The course of the St. Lawrence river is believed to be determined by a deep thrust fault of the Palæozoics to the south against the crystalline Labrador shield to the north. This probability is more forcibly pronounced in the lower part of the river bounding the Gaspe shores than it is farther inland, for in Gaspe there is no single evidence that this river traverses the crystalline shield in such direction as to leave any part of the crystallines to the south. This highly significant directive fault line was long ago located by Sir William Logan and is commonly known as "Logan's fault". Along this fault plane and

against the crystalline horst behind it (north), the palæozoics have been shoved and overthrust, here as elsewhere throughout the 2,000 miles (3,600 km.) extent of the Appalachians, to the southwest, but here with the sharp crescentic curvature not elsewhere shown. The Island of Anticosti, which lies 60 miles (108 km.) east-northeast of Cape Gaspe, is an area of horizontal Silurian rocks outside the region of folding,—a *parma* lying between the horst and the Appalachian folds.

FOLDS.

From the St. Lawrence river shore southward to Percé the folds of the strata are exposed and certain fairly definite anticlinal courses across them were determined by Logan and in large measure confirmed by later observers. These are apparently five in number, beginning at the north:

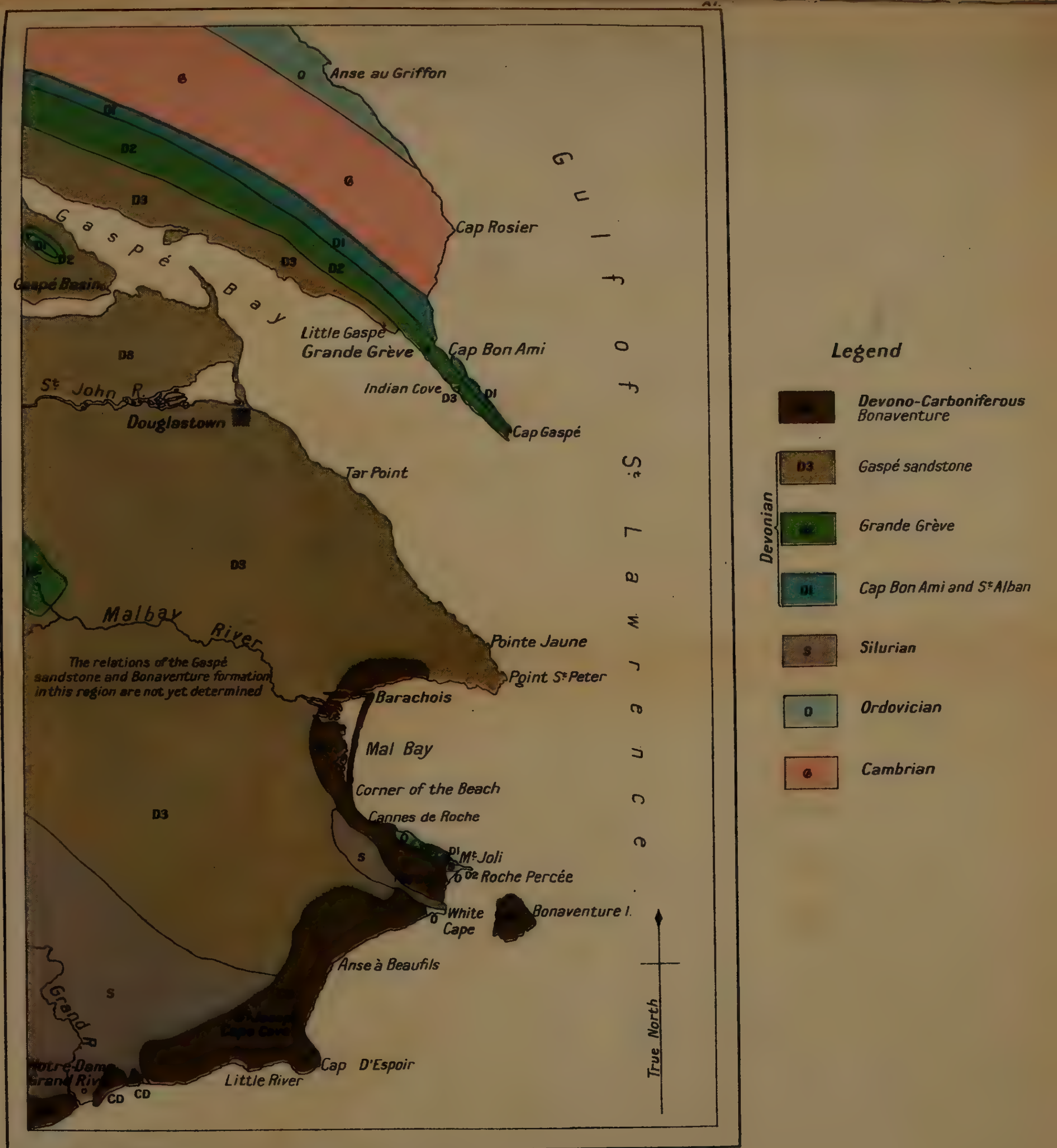
1. Forillon anticline (overthrust);

2. Haldimand anticline; the axis runs through Gaspe mountain (Gaspe basin) and enters the bay at Cape Haldimand. In the trough between folds 1 and 2 lie the upper reaches of Gaspe bay and the lower course of the Dartmouth river or Nor'west arm.

3. Tar Point anticline; strikes the bay at Tar point on the south shore of Gaspe bay. Between it and fold 2 lies the barachois at Douglastown and the lower course of the St. John river which flows into it.

4. St. Peter anticline, meeting the sea at Point St. Peter.

5. Percé anticline. This is by far the steepest and most extensive of all the folds and is badly broken down at its sea end. Between it and fold 4 lies Mal Bay, its barachois and river. South of Percé the folds have been obscured by the mantle of the overlying Bonaventure formation (Devono-Carboniferous) which is feebly folded at the north end but this folding is of a much later date than the fundamental folds. This covering of red rock is spread over the south and southeastern parts of the peninsula and lies everywhere on the almost vertical edges of the great series of Ordovician-Silurian (mostly the latter) light gray and blue limestones.



Geological Survey, Canada.

Eastern Part of Gaspé

Miles
1 0 5 10
Kilometres
1 0 5 10 15

ORDER OF SUCCESSION.

In proper order of succession, the earliest rocks are exposed on the St. Lawrence river shore in a narrow belt of black Cambrian or Cambro-Ordovician shale to be seen at Cap Rosiers and thence up the river (*Rosiers shale*). Following immediately south (see map for position and direction of these belts) rise the steep cliffs of Lower Devonian (*St. Alban, Bon Ami* and *Grande Grève* beds). In the ascent from the low wave cut plateau of Cap Rosiers to the heights of the Bon Ami cliffs, one traverses the thrust plane between the Rosiers shale beds and the St. Alban lime shales, along which most of the Ordovician and all the Silurian to an unknown thickness has been squeezed out.*

This is the *Forillon fold*, the southern flank of the Cap Rosiers overthrust. In it the Devonian St. Alban, Bon Ami and Grande Grève beds, all conformable, are inclined quite uniformly west of south at angles of 25°-30°, but the Cambro-Ordovician Rosiers shales on which they lie are almost vertical and always highly distorted. It is not now possible to estimate the degree of this overthrust or extent of the Devonian cover but it would seem to have at least extended 8 miles (14·4 km.) seaward to the 50 fathom line. If the Silurian has actually been squeezed out by the overthrust it is probable that a formation of very great thickness has thus disappeared from the succession, for at the Black Capes on the Bay Chaleur shore, the Silurian, in the most complete Silurian section yet known in the Gaspé peninsula, is upward of 7,000 feet (2198 m.) in thickness.

The St. Alban and Bon Ami beds are sparsely fossiliferous, but the conformable Grande Grève beds of purer limestone are highly abundant in species typical of the earliest Devonian limestone beds, Helderberg and Oriskany At the north neither of these formations is anywhere well exposed except on the little Forillon peninsula though both extend inward (west) into the timbered heights of the northern mountain ridges.

Two remote and detached masses of this early Devonian limestone at Percé, 15 miles (27 km.) due south from the

* There is an alternative reason to believe that the Silurian is absent at the north by extinction of the deposition, but this construction of the section would only lessen the amount and not the mode of destruction by the overthrust.

Forillon, constitute the most brilliant and striking scenic features of the Gulf coast: 1. Percé Rock (*Le rocher percé; L'isle percée*), 2. Les Murailles. These limestone masses carry a smaller fauna, in some measure distinct from that of the Grande Grève beds, but their identity of age is unquestioned. Further special reference is made in the proper place to them and to the Ordovician and Silurian cliffs of Percé.

Next south and overlapping unconformably the Devonian limestones of Grande Grève is the broad band of *Gaspe sandstone*; so named by Logan. This is a heavy mass of red, brown and grey sandstone with many coarse pebble layers. Contact of the basal beds with the limestones is to be seen on the Forillon peninsula at Little Gaspe and at several places from Grande Grève out to Cape Gaspe there are infaulted masses of the sandstone in the limestone beds, which indicate that the coating of sandstone has been stripped from the latter. Cliffs of Gaspe sandstone are exposed on all the south shore of Gaspe bay, at Chien Blanc, Point St. Peter (the south cape of the bay) and thence into the north shore of the Mal bay where their identity is gradually lost by conformity in composition to the overlying Bonaventure conglomerate. From measurements of the shore sections supplemented by traverses of the great expansion of these sandstones in the interior, Logan inferred a total thickness of more than 7,000 feet (2,198 m.). Ells has rightly believed this figure too high on account of faulting, but the amount of duplication from the displacement and the actual lines of faulting have been difficult to decipher on account of the homogeneity of the strata. The Gaspe sandstones contain an abundance of terrestrial plants which have been described by J. W. Dawson and indicate middle Devonian affinities. The marine fauna of the sandstone is profuse at certain low levels in the series and these species are characteristic survivors of the Grande Grève fauna with an addition of species of later Devonian date, identical in large part with the Hamilton (middle Devonian) species of New York.*

*Of these fossiliferous localities of the Gaspe sandstone, it may here be stated that those which have been most carefully studied lie at the rear (west) of the first hill behind Gaspe Basin at the head of Gaspe bay and thence north to L'Anse-aux-cousins and Pointe Naveau on the Dartmouth river; at Friday's bluff on the St. John river about 30 miles (50 km.) west from Douglastown and along the courses of the Mississippi and other brooks tributary to the York river, about 35 miles (63 km.) in from the coast.

The Bonaventure formation. Beginning with the south shore of Mal bay, is a great mantle of red conglomerates and sandstones which covers all the coast regions from here south over the whole Bay Chaleur region, save where it has been torn away by sea and weather and left the underlying formations exposed. The name Bonaventure was given by Logan and was taken from Bonaventure island off the coast of Percé which is entirely constituted of these conglomerates though they rise to greater heights in Mt. Ste. Anne at Percé (1,200 feet). The formation is almost horizontal throughout its extent, but the gentle undulations of its northern portion are admirably expressed in the broad rolling summit of Mt. Ste. Anne. This Bonaventure formation is in part of distinctly continental origin but its heavy conglomerates have doubtless been piled together along a rough coast not unlike that which now faces the Gulf. These conglomerates are in considerable measure composed of blocks and boulders of the fossiliferous rocks beneath, Cambrian to Devonian, and they are frequently of enormous size, having in one instance a weight of 8 tons, the angularity of this fragment indicating that it had fallen from an overhanging sea cliff. The Bonaventure formation is believed to represent the later stages of the Devonian and the early stage of Carboniferous time, indeed all of the latter that is recorded by deposits on the peninsula. It is also the youngest rock formation in Gaspe. By the early observers it was considered as altogether of Carboniferous age and was correlated with the red sandstones of Nova Scotia, Prince Edward Island and the Magdalen islands which are now known to be of Permian age. Ells was the first to recognize a distinction in the composition of the conglomerates and thereupon based a distinction in age, calling the lower or limestone conglomerates, Devonian, and the upper beds with fewer lime and more crystalline pebbles, Carboniferous, a difference not easy to recognize at many localities.

The limestone conglomerates at the base are clearly exposed at and about Percé, and the upper beds in the summits of Percé mountain. In the outcrops on the Bay Chaleur shore, this distinction is much obscured and the red sandstones and conglomerates with jasper pebbles lie everywhere on the upturned edges of the grey Silurians often producing brilliant colour contrasts. The total original thickness of these Bonaventure beds is not known.

In Mt. Ste. Anne, Percé, they stand at 1,200 feet (370 m.) and in the Carleton mountains at Carleton, Bay Chaleur, at nearly the same height. They contain no contemporary animal remains so far as known, but plant remains, as yet undetermined, and even thin coal layers, have been found in the fine sandstones of Cannes-des-Roches on Mal bay.

PALEOGEOGRAPHY.

The ancient geography of this region has already been intimated. In Cambrian, Ordovician and Silurian stages the sea way or channel, bounded by the old land at the north and south, was broad and uncomplicated, forming an open passage from the north transatlantic strand into the waters of the Appalachian interior. During Silurian time especially, this passage following the Appalachian synclinal was nearly as broad as the Gaspe peninsula and we have as yet no evidence that it was greatly obstructed. So far as known its faunas, as well as those of the Ordovician bear a decided Atlantic (transatlantic) aspect. The upfolding of these strata constructed new and narrow channels at the opening of the Devonian, but these were clear and the faunal correspondence between them and contemporary deposits of the interior is very close.

Regarding these Devonian channels it may be said:—

(1) There was a definite and open passage from Gaspe into New York and the southern Appalachians during the period of the earliest Devonian (Helderbergian) when a well defined element of the Helderberg fauna flourished in the St. Alban beds.

(2) A similar open way existed at approximately or actually the same time, connecting the Dalhousie beds of northern New Brunswick with the Helderbergian of the interior.

(3) These two passages seem to have converged and united toward the west and south, for while each carries a clear predominance of Helderberg species the two have comparatively little in common.

(4) In the later stage represented by the Grande Grève limestones the northern passage became broadened while the Dalhousie channel became extinct. In addition to these open passages from the interior outward were others of Devonian date further south, and the relations of these sea ways have been discussed by Clarke (**11,** p. 153-162.).

5) The Gaspe sandstones indicate a general breaking down of the barriers of the northern channel which permitted a later (lower or middle) Devonian invasion of species from the interior, while the Grande Grève fauna still persisted. Flood and barachois conditions governed the early deposition of these sandstones but encroaching elevation eventually changed the middle and later Devonian conditions to those of a rias coast not unlike that of the present.

THE ORIGIN OF THE GULF OF ST. LAWRENCE.

The hydrographic charts of the Gulf indicate very clearly that the course of the ancient St. Lawrence river was from its present mouth southeast, far to the east of Gaspe, east of the Magdalen islands, and thence outward to the Atlantic by the passage between Cape Breton island on the west and Newfoundland on the east (Cabot strait). The St. Lawrence river is a very ancient waterway and takes its date from at least as early as the time of the marine (Lévis) channel of the early Ordovician, a passageway which led from Atlantic waters into the Appalachian gulf of the interior of the continent. Fixity was given to this waterway by the long subsequent faulting of the Palæozoic rocks against the crystalline Labrador shield at the north, and ever since this factor became efficient the passage has been now and again a salt-water channel and a fresh-water drainage way. That part of the river channel now submerged beneath the Gulf waters is not the oldest portion but a later part of the river, where the valley was cut out through marine rocks which had been deposited over the bed of the Gulf when that was open ocean.

The orogenic axes of Appalachian disturbance through the Gulf region are twofold: that at the south, passing through Nova Scotia and on into Newfoundland keeping a N.E.-S.W. trend without change of direction; that at the

north, passing through Gaspe, curving at its termination in an arc, convex northward: thus:

Orogenic Appalachian axes. Gulf of St. Lawrence.

The torsion of the northern fold, ascribable to the resistance of the Labrador shield, produced a syntaxis which broke down that fold and dislocated the bottom of the Gulf area in a line continuous in direction with the course of the fold. Thus with the fracture of the pavement of the region and the consequent differential elevations and depressions, the St. Lawrence waters took somewhat the course now indicated by the hydrographic chart; probably for a part of the time or by way of a subsidiary channel taking the passage out by the Strait of Belle Isle and bending about Anticosti island to the north and east. This was thus a secondary condition of the river, dating to a time subsequent to the uplift of the folded Palæozoic rocks. Since that time, the broken down Gulf region has successively been a river way, an open marine body, an estuarine basin, and again a more or less enclosed sea. After the recoil of the northern fold which broke down the regularity of the mountain building and left the parma of horizontal rocks at the north (Anticosti island), came a period of rough rias coast along the broken ends of the Appalachian folds with a sea which received the mantle of Bonaventure conglomerate, when the marine waters had a far wider westward extent than to-day and the river channel south of the latitude of Percé was deeply buried. This period was followed by a shallowing of the basin which brought on the estuarine conditions of the coal period, with occasional irruptions of marine conditions; then a still farther elevation of the gulf bottom, which

resulted in broad coastal sand plains under comparatively arid climate, during which the red Permian sands of Nova Scotia, Prince Edward Island and the Magdalens, with their sand-etched boulders, were laid down. With the close of the Palæozoic the lower channel of the river across the Gulf region was high, the rock land on the west and east extended close to it so that the channel now buried in the Gulf was then the efficient river channel. The cutting down of the land into its present broken coast line and scattered islands and the submergence of the river channel have taken place since the opening of Mesozoic time.

GLACIAL AND POST-GLACIAL PHENOMENA.

Gaspe does not appear to have been within the reach of the great continental ice sheet. Its glacial phenomena are scattered and evince only movements of land ice downward from the mountains of its interior and deposits of this origin are everywhere complicated with sea ice transportation; thus every northern boulder is under suspicion of having been brought in by floating ice. The islands off the coast, Prince Edward Island and the Magdalens, are unglaciated.

Elevated beaches are to be found at various points on the peninsula. These are widely scattered and show evidence of Pleistocene warping as in the case of the terraces exposed at Gaspe basin.

DETAILED DESCRIPTION.

PERCÉ.*

L'Anse-au-Beaufils, the station for Percé, lies on the coast 5 miles (9 km.) to the south.

From L'Anse-au-Beaufils, Bonaventure island, from which Bonaventure formation takes its name, is seen at the east and the Percé mountains at the north. The road to Percé leads from here due north and crosses Cap Blanc or Whitehead.

View of Percé from the Summit of the Road over Cap Blanc.—The village (shire-town of Gaspe county) is on a triangular rock plateau, with Mount Joli at its apex,

*See Maps—Percé and vicinity, and, Percé.

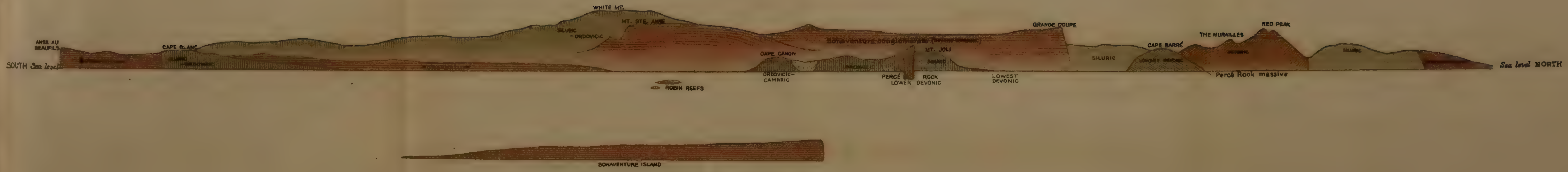
facing the Percé Rock; Bonaventure island 2 miles (3·6 km.) long, 3 miles (5·4 km.) out to sea; at the left Mount Ste. Anne 1,200 feet (370 m.) A. T.; on the further side of the triangle the ragged sea cliffs (Les Murailles), which front on Mal bay; the north side of Mal bay is formed by Point St. Peter with Plateau island and on the distant horizon at the right is Cape Gaspe (Shiphead). Beyond is the St. Lawrence river.

Percé Rock.—This noteworthy insulated cliff, anciently the *Isle percée*, early in the history of the settlement gave its name to the mainland. L'Isle percée, le rocher percé, Pierced rock, Split rock or Percé rock, as it is variously termed, is 2,100 feet (646 m.) long from prow to the outer end of the rear obelisk, 300 feet (91. m.) wide in its greatest breadth and 288 feet (87 m.) high at its prow. The arch through it is 60 feet (20 m.) high. In plan its form is somewhat angular or zigzag and viewed from in front resembles a giant steamer coming into port.

The rear obelisk is the outer flank of a second arch which fell in 1845. Back in the early 1600's there seem to have been two other arches toward the seaward and thinner end, and the wastage of the rock has been effected within recorded time largely by the downbreaking of these arches. There is still another arch in the rock, transecting the obelisk parallel to the major axis of the mass. The wastage of Percé Rock under the impact of the waves is very slight. Freezing and thawing are more efficient agents but during the past ten years not enough has fallen from all these causes combined to alter the outline of the cliff in any perceptible degree and the line of the prow has not materially changed in 150 years. At high tide the Rock is isolated, but at low tide a batture or sandbar extends to it from the foot of Mount Joli affording ready access to the point and south side of the cliff. The north side is accessible only by boat. The sheer sides of the Rock make attempts to scale it exceedingly perilous and such attempts are now forbidden by municipal ordinance.

Fossils abound in these strata, distributed in thin layers with barren interspaces. They correspond in characters and association with the richer fauna of the Grande Grève limestones, and the Percé Rock massive is correlated with that formation (see p. 90). Forty-four species have been described, of which 31 occur in the Grande Grève

PANORAMA SKETCH OF THE SEA FRONT AT PERCÉ



Panorama of Percé from the south.

beds. Characteristic species are *Dalmanites* (*Probolium*) *biardi*, *D. perceensis*, *Phacpos logani*, *Chonetes canadensis*, *Chonostrophia complanata*, *Spirifer arenosus*, *S. murchisoni*, *Leptocœlia flabellites*, *Rensselaeria ovcides*.

No other trace of the formation and fauna represented by Percé Rock is to be found in this vicinity except in the *Murailles* or sea cliffs which lie beyond the North Beach and face the Mal bay. The grey headland of Cape Barré with which the Murailles begin, is followed by a faulted and overthrust mass of highly coloured strata, dipping S.E. 20° and abutting against the Cape Barré strata, containing, sparsely, the fossils of the Percé Rock strata. These inclined strata rise to the high peaks of the Murailles but their tops are there coated unconformably by a layer of the limestone conglomerate of the Bonaventure series.

The observer will not fail to notice the colony of waterfowl nesting on the green capped top of the *Isle perce*. This settlement is composed only of the Herring gull (*Larus argentatus*) and the Cormorant (*Phalacrccorax carbo*), an association which is repeated on the cliffs of the Forillon peninsula 17 miles (30 km.) to the north (see note beyond on the bird colony of Bonaventure island).

Percé Rock is composed entirely of Lower Devonian limestones standing nearly vertical (dip 80° S.E.) and highly tinted with iron yellows, reds and purples. Its strata are seamed with calcite veins of white, red and deep brown, often with interesting crystallizations. The combination of rock colours with the green cap of verdure produces striking effects which vary with every change in atmospheric conditions and the position of the sun.*

Cape Barré.—This is the southern point of the Murailles, bounding the North Beach. Its strata are thin, sandy, blue grey shale and limestones dipping 30°-40° N.E., the red rocks of the Percé massive being faulted against them. These rocks contain only a few fossils, all of Lower Devonian type (*Spirifer* cf. *modestus*, *Leptostrophia oriskania*, *Conularia* cf. *lata*), the most significant being a species of the trilobite Dicranurus (*D. limenarcha*) of which only two other species are known, both from the

*For an account of the history of Percé Rock in the records of Gaspe, of its changes in form, rate of degradation, total fossil contents, etc., see Clarke [9].

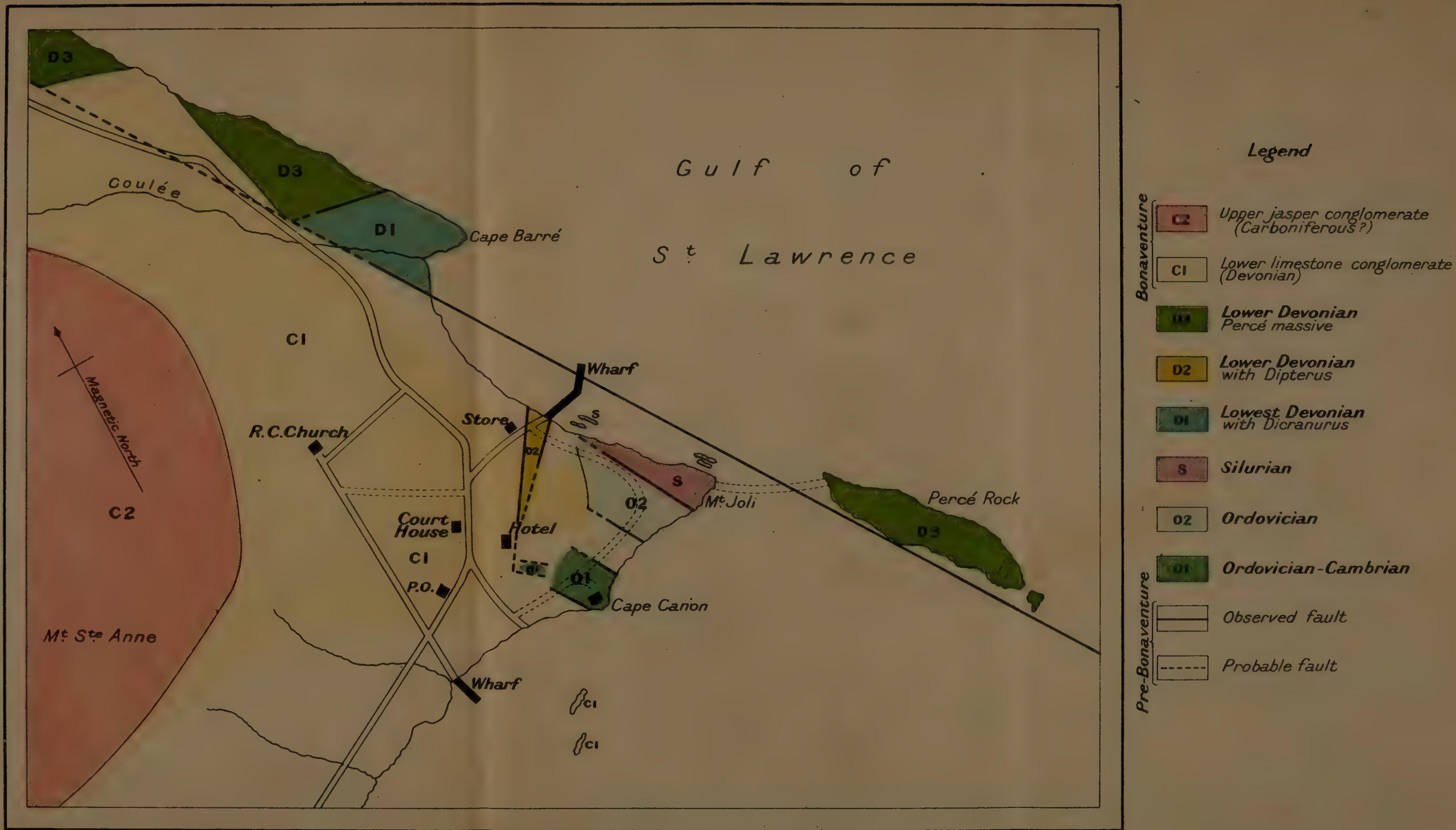
Lower Devonian, one of Bohemia and the other of New York.

These beds are not distinctly developed elsewhere in the region and they appear to represent a Devonian stage earlier than that of the Percé Rock.

The Rock Wall between the North and South Beaches.—Just at the steamboat wharf on the North Beach recent excavations, now covered, exposed a grey, steeply inclined shale carrying *Dipterus*. No other fossil has yet been determined from this shale which is regarded as belonging to a Devonian stage beneath that of the Percé massive. This shale is apparently faulted against the Silurian at the south and limited at the north by the fault lines of the beach. Following the shore southward the first outcrop is of the erect grey limestones and shales of Mount Joli. The rock exposures begin with the reefs exposed at low water to about 400 feet from the shore and the Mount Joli cliff as a whole has a sea front of about 700 feet (211 m.) and the same dip as the Percé Rock strata. This would give the formation here an approximate total of 1,100 feet (335 m.). There is little change throughout in its lithic characters, but there is clear evidence of a displacement within the mass which gives a geological meaning to the division of the massive into a *north flank* and a *south flank*. The beds of the north flank afford admirable exhibitions of jointing and ripple marks and in both flanks fossils are to be found in thin beds with barren intervals. In the north flank are the corals *Duncanella*, *Zaphrentis*, *Streptelasma* and *Pleurodictyum*, the graptolite *Monograptus* cf. *clintonensis*, the brachiopods *Dalmanella*, *Leptæna* (*rhomboidalis*), *Stropheodonta*, *Spirifer* (cf. *niagarensis*, *modestus*) and an uncertain *Phacops*: all of which indicate a Silurian stage.

In the south flank of Mount Joli are the trilobites *Ampyx*, *Tretaspis*, *Calymmene*, *Trinucleus*, *Pterygometopus*, *Ptychopyge* and *Illænus*, the brachipods *Dalmanella*, *Rafinesquina*, *Strophomena*, *Parastrophia*, *Zygospira*, the assemblage indicating a middle or later Lower Ordovician stage. These beds seem to extend across the mountain and just touch the other shore near the wharf house.

This exposure ends abruptly at the south in a short beach covering a fault, beyond which is *Cap-du-Canon*, a mass of erect, dark argillaceous and calcareous slates, much crumpled and glazed. The general inclination



Geological Survey, Canada.

Percé, Gaspé

(Scale of map is approximate)

of the bedding is not different from that of the Mount Joli massive, but the beach interval, continued over the surface of the ground as a swampy depression, is indicative of their discontinuity.

Not far landward of this cliff is an isolated boss of limestone conglomerate which is apparently a part of the same mass, though its much more massive calcareous character indicates a part not there represented and possibly cut off from that by a displacement. No fossils have been with certainty derived from these rocks,* but their age is probably Ordovician or Ordovician-Cambrian.

The Cap-au-Canon can be passed only at a low stage of the tide, and with it the rock section ends at the South Beach.

Mount Ste. Anne.—This mountain (1,200 feet, 370 m.) rises just behind the village, exposing toward the sea its upper precipitous face of red conglomerates. A grassy road leads up to the mountain on the north side, but on nearly all other sides the mountain faces are vertical fault walls. The view from the summit is fine with clear weather, affording a panorama of the coast, its capes and islands, from the St. Lawrence river at the north to the Bay Chaleur at the south, and of the rolling wilderness of the hinterland. Ste. Anne is the foremost of a mountain cluster known as the Percé mountains and is the only member of it that is composed of the *Bonaventure conglomerate*. The ascent of the mountain shows limestone conglomerates in the lower part and jasper conglomerates above. The attitude of these beds approaches the horizontal at the south, but is undulating and dips gently down toward the north. The mass everywhere sheets the upturned broken and eroded edges of the vertical Ordovician-Lower Devonian cliffs, and it here reaches its northernmost limit in recognizable expression. At more northern points a distinction between these conglomerates and the Gaspe sandstones is obscure but there are reasons to believe that the upper sands and conglomerates on the south shore of Gaspe bay, which have been included in the Gaspe sandstones, pass without much change of attitude into the Bonaventure formation.

* The limestone boss was formerly a place for lime burning, but the limestone for this purpose was brought from Cap Blanc and the Ordovician fossils that have been referred to this outcrop may have come from the more distant locality.

The mass of Mount Ste. Anne is peculiarly isolated by a series of fault scarps one of which fronts the sea at the east; a second, the Grand Coupe, faces the north; and a third, the Amphitheatre, lies behind the mountain facing the southwest and separates the mountain mass from the zone of Silurian limestones which almost encircles it.

The throw of these faults is indicated by the fact that the exposed beds of conglomerate seen in the coast ledges south of the South Beach and thence on southward to Cap Blanc are mostly of the middle and upper beds carrying jasper pebbles with a few fossil-bearing limestone and slate pebbles. These intimate a displacement of approximately 1,000 feet (300 m.). (See under Cap Blanc).

Cap Blanc or Whitehead is the sea-end of the southern rock ridge bounding the Percé triangle. It is a mass of light grey Ordovician limestones, having the steep dip (80° SE.) of all Palæozoic strata here lying beneath the Bonaventure formation. In approaching the cape from the north these limestones are seen to rise gradually from the sea, and are overlain by the slightly inclined basal beds of the Bonaventure conglomerate. The entire series of the lower beds is overturned, the Ordovician lying above the Silurian. The first or northernmost of these are latest in age and they alone in the series are tinted red and greenish, but soon pass into grey. Probably some part of the red stain in these beds has been derived from the red Bonaventure over them. The overlapping beds soon disappear leaving the erect strata standing alone and giving name to Cap Blanc which is conspicuously white by contrast to the red rocks about it. Just beyond the point of the cape these grey limestones are cut off and terminated by a sharp fault against the Bonaventure beds, the former having moved down, as shown by the down-dragged edges of the Bonaventure. Access to the cliff for purposes of examining the rocks is difficult except at low tide in a gentle sea.

The lower and later red-greenish beds contain some fossils in abundance: *Favosites* (cf. *hisingeri*), *Halysites catenularius typicus*, *Lyellia*, *Callopora*, *Cladopora*, *Lichas*, *Chonetes* (type of *novascotica*), *Catazyga* or *Zygospira*: enough to indicate a Silurian age, though most of the species have not been determined. The grey beds farther south are sparsely fossiliferous but carry an Ordovician fauna as early as the Trenton and comparable to that of

Mount Joli-south flank:—*Phacops primævus*, *Calymmene senaria*, *Ceraurus pleurexanthemas*, *Camarospira bisulcata*, *Zygospira recurvirostra*, *Bolboporites*, etc.

The total thickness of these limestones approximates 1,000 feet (300 m.) and there is no evident displacement within the mass. Their relations otherwise conform closely to the beds of like age in the Mount Joli section, though there is no noticeable degree of identity in the species of fossils which occur in the two sections.

Bonaventure Island—This island, 2 miles (3·6 km.) long, 1½ miles (2·7 km.) wide and 3 miles (5·4 km.) out to sea, is separated from the mainland by a channel in which the tidal currents run heavy. The island is an ancient fishing site dating back to the days of the 16th and early 17th centuries when Basques, Bretons and the men of La Manche came out every year for the fishing, returning to France in time for the lenten market. The rocks of the island are entirely of the Bonaventure conglomerate and represent the upper beds, the basal limestone conglomerate not being present. It is thus, in the present interpretation of the formation, a mass of Carboniferous rocks. The island presents a low face on the channel side but the cliffs on the east rise to 400 feet (120 m.) making a noteworthy fault face. These cliffs have an added interest because of the large colony of water birds which nest here. The assemblage is not surpassed in size anywhere in the Gulf except on the celebrated Bird Rocks of the Magdalen islands which politically belong to Gaspe but lie 160 miles (288 km.) out to sea. The species nesting here are the gannet (*Sula bassana*), Kittiwake (*Rissa tridactyla tridactyla*), Brünnich Murre (*Uria lomvia lomvia*), Puffin (*Fratercula artica artica*), Razor-billed Auk (*Alca torda*) and perhaps one or two more—an association entirely like that on the Bird Rocks. In these Gaspe waters there are two bird assemblages of this kind and two other associations which consist only of the Herring Gull and the Cormorant. It is a curious coincidence that the former and larger assemblages, alike in kind, nest only on the horizontal ledges of Carboniferous sandstones while the lesser combination breeds only on the inclined strata of the Lower Devonian limestones.

The Girdle of Ordovician-Silurian from Cap Blanc (south) to Corner-of-the-Beach (north).—From Cap Blanc this heavy mass of overtipped limestones passes inland, bounding the

south flank of Mt. Ste. Anne, then passing behind that mountain, rising to greater heights and forming the broken range known as White mountain, which almost encircles and isolates Mt. Ste. Anne, approaching sea level at Corner-of-the-Beach on Mal bay. A fault-bounded outlier of this rock may be seen in a white cliff on the sea front beyond the Murailles, where it lies at an angle against the Bonaventure beds beyond. Much remains to be learned of the fauna of this extensive belt of limestones.

GEOLOGICAL RELATIONS.

The foregoing account of the leading topographical and geological features has intimated the geological history of Percé. The steeply tilted older strata present the seaward end of an Appalachian fold of great magnitude, which has been variously broken down. The uniformity of the inclination in the steep fold is expressed by the coincident dip of all the older beds, 80°-85°SE., and this fold, steeply inclined to the north, involves beds from (Cambrian) Lower Ordovician into upper Lower Devonian.

The construction of the tectonic changes here is complicated, perhaps not altogether clear, but the secondary movements expressed by dislocations of the strata are of two orders in time. Of the older faultings there are unlike orders in magnitude. The great Percé fold, exposed only at its sea edge, may be construed as typically Appalachian in its thrust northward. It was an earlier fold than those to the north of it, and was not thrust against a horst of crystallines. The over-tipped Silurian and Ordovician strata present in the Mount Joli section and repeated 2 miles south at Cap Blanc, indicate a profound displacement along the thrust plane after folding which carried southward the inverted succession of the strata; a displacement which would involve the conception of gravitational movement backward (south) along the plane of thrust; a conception apparently reasonable, and squaring with carefully repeated tests. The lesser displacements involved in the downbreaking of the Percé fold are indicated on the accompanying map in which those of earlier age are marked by single lines, and those visibly affecting the Bonaventure formation only, by double lines, in both instances dotted where the break is uncertain. Percé Rock is evidently bounded on its long sides by faults which have isolated

it wholly and cut out from beneath it the earlier Devonian stage represented by the rocks of Cape Barré and the wharf-foot. This cut-off mass of Devonian extending along the face of the Murailles has itself been faulted across, as indicated.

The beach depressions both north and south are undoubted displacement areas, the first being the interval between the Devonian of the Murailles and the Silurian of Mt. Joli (North Beach); the second or broad South Beach being the area of general breaking down of the great arch.

The displacements which took place at a later date than those mentioned have visibly affected only the Bonaventure conglomerate. These may be thus enumerated: (1) The seaward scarp of Mt. Ste. Anne. Bonaventure island seems to be the downthrown mass from this displacement, the "Robin reefs" lying off the South Beach remnants of the same mass; (2) The strata of Bonaventure island dip slightly to the S.W. and the sheer cliffs of the northeast front are a fault face. At the foot of these cliffs the bottom drops immediately to 30 fathoms; (3) The Grand Coupe at the north; (4) The Amphitheatre at the back of Mt. Ste. Anne.

Relative Thickness of the Older Palæozoics at Percé.

Devonian	Percé beds in Percé Rock 250–300 feet but probably rising in Les Murailles to	500 ft. (153 m.)
	Cape Barré Beds	100 ft. (33 m.)
Siluro-Ordovician	Mt. Joli massive	1,100 ft. (339 m.)
	Cap-au-Canon massive	600 ft. (200 m.)
		2,300 ft. (725 m.)

The thickness of the strata at Cap Blanc which are doubtless a repetition of part of the foregoing beds, is 800–1000 feet (303 m.). The estimated thickness then of the pre-Bonaventure beds at Percé [Lower Devonian-Ordovician (Cambrian?)] is about 2,000 feet (606 m.), without making allowance for loss by faulting.

GASPE.

The terminus of the railway is at York on the south side of Gaspe Basin, passing an instructive cut through the Gaspe sandstones (Middle Devonian). These are however not the lower beds with marine fossils, but the plant-bearing strata which at this point probably lie above the marine beds. Crossing by ferry to the Gaspe side, the Gaspe sandstones may be seen near the landing dipping at a steep angle to the north. Gaspe bay lies in a synclinal of the sandstones, that is, in an ancient Appalachian trough the other arm of which constitutes the hill slopes on the north side of the bay where the dip is to the south. The marine fossils occur for the most part in strata behind the Gaspe mountain and up the Dartmouth river (at the north), distances of 3 to 4 miles from Gaspe Basin. The fossils are Middle Devonian species of the interior or New York sea commingled with more or less local Lower Devonian types which have survived from the period of the Grand Greve fauna.

GRAND GRÈVE AND THE FORILLON.*

Grande Grève, 14 miles (22·5 km.) distant by water from Gaspe, is a little fishing settlement on the peninsula of the Forillon. This Forillon peninsula bounds the north side of Gaspe bay and lies between that bay and the St. Lawrence river. At its upper end and near the head of the bay it has a width of 20 (32 km.) or more miles, but at Grande Greve and thence to the Cape, a distance of 4 miles (6·4 km.), its width does not exceed ½ mile (0·8 km.). As elsewhere observed, this part of the Forillon is a single Appalachian ridge sliced vertically in half along its axis, its end at Cape Gaspe making the easternmost seaward face of the Appalachian system. From Grande Grève westward the ridges are multiplied in number by the accession of the slate cliffs at the north, but from Grande Grève east the half ridge alone remains, though furrowed on its surface by a coulée which gives the cape a double head; the northern, Cape Gaspe; the southern, Shiphead.

Only the south flank of this ridge remains and the dip of the strata—almost coincident with that of the hills—is toward the south, while their cut-off edges form the high cliffs which face the St. Lawrence river.

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*See Map.—The Forillon, Gaspe.

AI.

Geological Survey, Canada

The Forillon, Gaspé

Miles
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Kilometres
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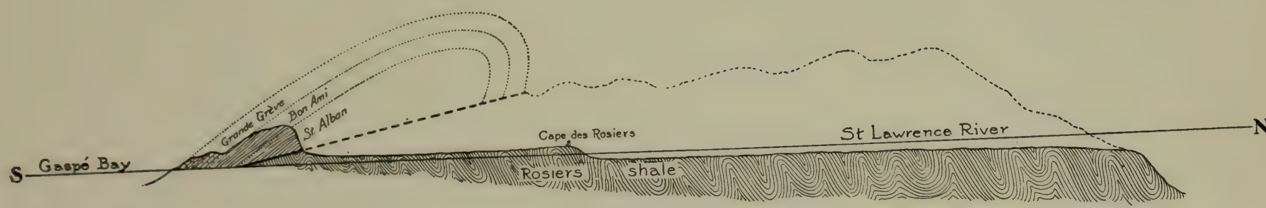


North-south section across the Forillon peninsula, Grande Grève to Cape des Rosiers, showing the overthrust of the Lower Devonian on the Ordovician-Cambrian.

We have here to deal with a heavy series of early Devonian limestones and lime shales unconformable to and overthrust upon the Cambro-Ordovician slates exposed at the north. The upper limestones, facing the south, are exceedingly rich in fossils, but the exposures are for the most part to be found on the little crescentic fishing beaches where the sea has cut out joint blocks of the strata. The thrust plane or base of the Devonian series has not yet been observed though further exploration may reveal it at the north base of the sea cliffs.

Starting from Grande Grève beach the section of the rocks is approached in reversed order, from top to bottom. Here and along all the neighboring beaches the upper strata of fossil-bearing Grande Grève limestones are exposed and actual unconformable contact of the uppermost beds with the red plant-bearing Gaspe sandstone is to be seen at Little Gaspe 1½ miles (2·4 km.) westward on the shore. The division of the total limestone series (St. Alban, Bon Ami and Grande Grève) is as yet a broad one based upon lithologic and faunal rather than diastrophic characters. The upper member of this series or Grande Grève limestone is also divisible on the basis of its fuana, into distinctive early and late elements, but taken as a whole the species of the Grande Grève member are eminently characteristic of the Helderberg-Oriskany with a considerable representation suggestive of incipient stages of the later Onondaga fauna of the New York standard. A total fauna of 155 species has been described from the Grande Grève limestone and a visitor may expect to find in the upper beds characteristic species of the trilobites *Phacops* (*logani*, *gaspensis*), *Dalmanites* (*phacoptyx*, *dolbeli*, *emarginatus*, etc.), *Probolium*, *Cordania*, *Lichas* and *Gaspelichas*; the cephalopods, *Kionoceras* and *Orthoceras*; the pteropods *Hyolithus* and *Conularia*; abundant gastropods of the genera *Platyceras*, *Eotomaria* and *Diaphorostoma*; the pelecypods *Pterinea*, *Megambonia*, *Palaeopinna*, etc.; a large array of brachiopods, *Spirifer arenosus*, *murchisoni* and many more, *Rhipidomella logani*, *Stropheodontas* and *Leptostrophias*, *Leptocoelia flabellites*, *Nucleospira*, *Rensselæria ovoides gaspensis*, *Megalanteris*, etc., etc. A very notable percentage of these species have a wide geographical rang and the affiliation of the fauna is distinctly American.

The lower beds of the Grande Grève division are exposed on the Kings road and carry an association of species which is most distinctively indicative of the Oriskany horizon; such as *Hipparionyx proximus*, *Rensselaeria ovoides gaspensis*, *Spirifer arenosus*, *Chonostrophia complanata*, *Rhipidomella musculosa*, etc. The limestones carry much nodular chert and in some places masses of silicious sponge spicules constitute the basis of the rock.*

Beneath the Grande Grève limestone lies a series of less purely calcareous, more magnesian beds, with but few fossils and these mostly diminutive forms,—a deposit formed under impeded marine conditions in which life was unable to flourish. These are the *Bon Ami beds*, and they form a large portion of the cliff face of the river escarpment. They can be examined on the face of Mt. St. Alban at the summit of the Kings road and at Cape Bon Ami, where a ladder down the face of the cliff at the end of the Portage road makes them accessible and they constitute the greater part of the bold front of Mt. St. Alban. Such fossils as they contain are quite distinctively of Helderberg age.

Beneath and conformable to the Bon Ami beds are the *St. Alban beds* with a fauna quite exclusively identical with the Helderberg (lowest Devonian) fauna of New York. These calcareous compact shales are to be seen in exposures along the shores of Cape-des-Rosiers cove at the foot of Mt. St. Alban. About 50 species have been identified from these rocks of which more than one half are found in the lower divisions of the Helderberg series in New York, while hardly more than one-fifth occur in the Grande Grève limestones. Access to these exposures requires the descent of the Kings road down the slope of Mt. St. Alban and thence across the fields to the shore of the St. Lawrence river.

Sir William Logan estimated the thickness of these limestones at 2,000 feet (610 m.) and of this the Grande Grève beds include approximately 600 feet (180 m.). The boundary, however, between the sub-divisions is not a sharp one, but in all, the beds afford a total not paralleled in the Devonian section at Percé. In fact the entire series is wanting elsewhere and in all the other Gaspe folds, so far as known, except so far as represented by the

*The fauna of all these Devonian beds has been described in detail by Clarke.

Percé Rock limestone which conforms faunally with the Grande Grève beds. The absence at Percé of the major part of the Devonian limestone series serves to indicate how extensively the formation has been lost by faulting out rather than by lack of continuity.

Unconformity between the Devonian limestones and the Cape-des-Rosiers slates.— Similarly the entire representation of the Silurian and Ordovician, as indicated in the Percé section (a minimum of 1,000 feet and probably much more), has been lost in the Forillon section, by the overthrust which has carried these Devonian limestones over the erect and distorted Rosiers slates of Cambrian (Cambro-Ordovician?) age. So far as we have any evidence, the vast overthrust of this Forillon fold is due to the resistance imposed by the crystalline horst lying at the north of the St. Lawrence river (Canadian shield) and the degree of the reaction is expressed both in the fold itself and in the great fault ('Logan's fault') which outlines the course of the river.

Relation af the limestones to Gaspe sandstone.— As observed, an actual unconformable contact of the limestones with the overlying sandstones is seen at Little Gaspe 1 ½ miles (2·4 km.) west of Grande Grève where the first ridge of sandstone mountains comes to the coast. Infaulted masses of these red sandstones in the limestones are also to be seen eastward of Grande Grève indicating the removal of an entire mantle of the Gaspe sandstone from above the limestones.

The Flora of the Gaspe Sandstone, by David White.— Gaspe is the most interesting locality for Devonian plants yet known in Canada. The Gaspe sandstones are remarkable for the abundant plant fragments, mainly representative of Psilophyton which occur in great numbers at some horizons, and which interestingly enough appear, at several levels, to be rooted in old soils. Fragments, frequently but slightly compressed, from this district are present in many of the museums of Europe, as well as in most of those in America. Gaspe was twice visited by Sir William Dawson, who described all the species reported from this region. The Psilophyton-bearing beds occur at many horizons in the section, one of the most interesting being near Watering brook on the north side of the bay. Several plant-bearing layers were described by Dawson as old soils. Associated with other plant remains are

numerous petrified trunks of the giant alga (*Prototaxites*) (*Nematophyton*). One trunk, partially exposed, was described as exceeding 3 feet (0·9 m.) in diameter.

At one place, near the middle of the section, a coal bed one inch to three inches in thickness, associated with highly bituminous shales abounding in remains of plants, and containing fragments of crustaceans and fishes, is said to occur in the midst of grey sandstones and dark shale which resemble ordinary coal measures. The coal, which is shining and laminated, has no underclay, and appears to consist of what was once a peaty mass of rhizomes of Psilophyton, which now lies between layers of laminated bituminous shale. This thin coal occurs near Tar point on the south side of Gaspe bay, a place named for the occurrence of a thick dyke of trap holding petroleum in its cavities. The coal is supposed to be of considerable horizontal extent, the Tar Point outcrop being provisionally correlated with a similar bed about 4 miles (6·4 km.) distant on Douglas river.

The plants described by Dawson from Gaspe include *Prototaxites logani*, *Prototaxites* (*Nematoxylon*) *crassum*, *P. tenue*, *Stigmaria areolata*, S. *minutissima* (the latter species being perhaps based on the rhizones of Psilophyton) *Didymophyllum reniforme*, *Calamites inornatus*, *Annularia laxa*, *Lepidodendron gaspianum*, *Leptophleum rhombicum*, *Lepidophloios antiquus*, *Psilophyton princeps*, *Psilophyton robustius*, *P. elegans*, *Arthrostigma gracile*, *Cyclostigma*, *Cordaites angustifolius* and *Parka* related to, though smaller than, the Scotch *P. decipiens*.

The plants in the Gaspe section represent the Psilophyton-Arthrostigma flora, which preceded the Archæopteris flora The genus Archæopteris is present practically everywhere in the floras of the Upper Devonian in Europe and America, whereas the typical *Psilophyton princeps*, including the spinous forms, together with *Psilophyton robustius*, *Psilophyton grandis* and *Arthrostigma*, are characteristic of a lower zone in both Canada and the eastern United States. This older flora which is found in the Chapman sandstone in Maine, seems hardly to have survived the Hamilton group, above which (especially above the Portage) the Archæopteris flora reigns to the close of Devonian time.

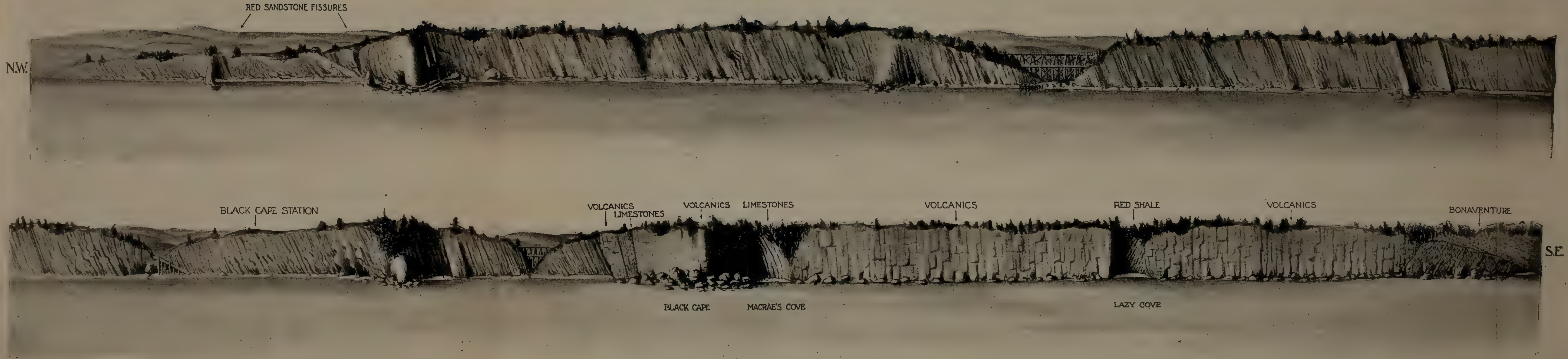
Extension westward of the Devonian limestone series.— In the direction of the mountain trend the limestones have been traced well inland along the course of the Dartmouth river and southward, but are here mostly exposed in the ridge summits by erosion of the sandstone mantle Their relation there to the rest of the Palæozoic series is not yet fully understood.

BIBLIOGRAPHY.

1. Logan, W. E.......Geology of Canada, 1863.
2. Billings, E........Descriptions of Fossils in (**1**).
3. Ells, R. W.........Report on the Geology of the Gaspe Peninsula: Rep't. Geol. Surv. Canada, 1880-82.
4. Ells, R. W... ....Report on Surveys made in 1883 in Gaspe: Rep't. Geol. Surv. Canada, 1882-84. Pt. E.
5. Low, A. P..... ...Report Geological Survey Canada, 1882-84.
6. Dawson, J. W......Fossil Plants of the Devonian and Upper Silurian of Canada, 1871 and 1882; also Quarterly Journal Geological Society of London, v. 15, 1859 and v. 19, 1863 (Plants of the Gaspe sandstone).
7. Billings, E.. .... .Palæozoic Fossils, v. 2, 1874.
8. Lambe, L. M... ..Contributions to Canadian Palæontology, v. 4, pt. 2. 1901.
9. Clarke, John M ....Early Devonic of New York and Eastern North America, v. 1, 1908. N. Y. State Mus. Mem. IX.
10. Clarke, John M...Sketches of Gaspe, 1908.
11. Clarke, John M...Relations of the Palæozoic Terranes in the vicinity of Percé, N.Y. State Mus. Rep't. Director, 1911.

BLACK CAPE SILURIAN SECTION.

Black cape on the north shore of the Bay Chaleur, is immediately east of the Little Cascapedia river and 70 miles (112 km.) from Matapedia. The rock section here is of special interest for its extraordinary development of the Silurian, the shore section from the mouth of the



The Silurian section at Black Cape, Chaleur bay.
(The lower part is continuous with that at the top)

35063—p. 111.

river named to Black cape itself displaying an unduplicated thickness of fully 7,000 feet, (2,130 m.) of strata.

In this Silurian section the strata are nearly all calcareous with intercalations of red shale near the top. They stand at high angles to the horizon, usually dipping 60-80° S.E., but these dips vary somewhat though without uncomformities. The eroded edges of the strata are overlain elsewhere in the region by the red sands and conglomerates of the Bonaventure formation, and there are several considerable fissures in the Silurian limestones of this section which are filled in with red sand derived from the overlying beds. All these occurrences indicate land exposure of the Silurians during all the early and middle Devonian time.

The base of the section at the west begins with greenish, highly nodular lime shales, very compact and heavy bedded, weathering out into irregular and gnarled shapes. These alternate with more highly calcareous shales and compact limestones of red and ochreous tints. These compact limestones contain Stricklandinias of great size (*S. gaspensis*, Billings) and in great number and with these are Spirifers of the *S. radiatus-niagarensis* type and occasional Whitfieldellas. Throughout the lower beds the rest of the fauna is largely of Stromatoporoids and corals which occur in enormous quantity and great diversity. There are Halysites of several species, having horizontal values, Favosites and Alveolites of great size, Heliolites, Syringopora, Eridophyllum in extensive colonies, Zaphrentis and other cyathophylloids in considerable variety. Additional species in these lower beds are Calymmene, Chonetes, *Atrypa reticularis* (Silurian type), Tentaculites, cyclostomatous gastropods, etc.

At an elevation in the series of about 1,500 feet (450 m.), where the scraggy limestones continue, there is some indication of change in the fauna by the addition of brachiopods of the genus Camarotoechia, Rafinesquina, the cephalopods Orthoceras, Trochoceras, etc. From Howatson's (elevation in section 1500 feet) eastward, the scraggy limestones continue as far as the breakwater. Then follows (at 6,500 feet or 1,980 m.) a heavy mass of sandy shale. This sedimentation continues sandy to near the end of the section which terminates at the volcanic mass forming Black cape, but toward the top the sands become interlaminated with thin beds of volcanic ash, with red and purplish shale and eventually calcareous and

variegated beds succeed to these, becoming in places compact limebanks entirely constituted of the debris of fossils.

These upper sandstones and sandy shales are remarkably profuse in corals, some of the species being palpably unlike those of the lower beds. The volcanic mass which forms Black cape itself and against which these upper strata abut presents a total sea face of 4,600 feet (1,400 m.) and within it are two notable inclusions or separate masses of Silurian strata. The first of these is in Macrae's cove, 600 feet (180 m.) from the beginning or base of the intrusive and the second at Lazy cove, $\frac{1}{3}$ mile (0·5 km.) further east. The intrusives are interbedded but the necessary study of the fossils is yet wanting to determine whether these fossiliferous masses are or are not additional parts of the section. At Macrae's cove the thickness of the sediments is 150 feet (45 m.) and in the narrower Lazy cove they are 75 feet (23 m.). These coves may be reached on foot along the beach by favouring tide. The volcanic cliff ends $\frac{1}{2}$ mile beyond Lazy cove and at its termination the red conglomerates of the Bonaventure formation lie against it at an angle of 30 degrees.

So far as at present indicated by the fossils, this section from base to top is of the age of the Niagara (exclusive of Clinton) or Rochester shale of the interior Silurian, though the assemblage will doubtless show a preponderance of Atlantic or European types which will bring it into more proper comparison with the Gulf sections at Arisaig and on Anticosti island. Its thickness is very great and in this respect the section overpasses any Silurian section known in America.

BIBLIOGRAPHY.

[Note.—The Black Cape section has only recently come under close observation. It has now been studied in some detail and the fauna assembled, but identifications and classifications have yet to be made.]

1. Logan, W. E. Geology of Canada, p. 447, 1863.

2. Ells, R. W. Geological Survey of Canada, Rept. for 1883, E. p. 27, 1884.

3. Clarke, John M. A Remarkable Siluric Section on the Bay of Chaleur. N.Y. State Mus. Rept. Director for 1911. p. 120-126. 1912.

A1.

Geological Survey, Canada.

Head of **Chaleur Bay**

Miles

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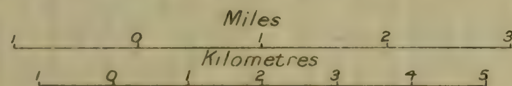
Kilometres

5 4 3 2 1 0 5 10 15

A.I.

Geological Survey, Canada.

Scaumenac Bay, Quebec



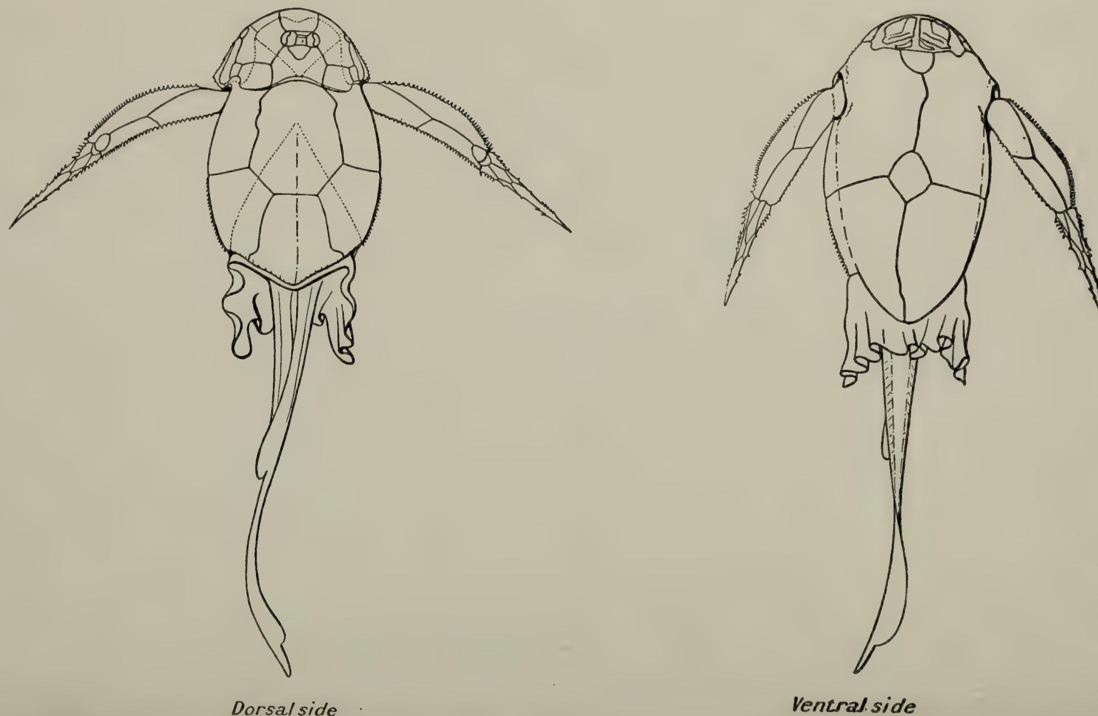
SCAUMENAC BAY.*

This is the locality of fish-bearing sandstones which are commonly regarded as of upper Devonian age. The beds face the water in layers having a low dip to the east, are bounded and overlain at the east by the red Bonaventure sands (Devono-Carboniferous) and at the west are limited, for this immediate region, by diabase intrusions. The inland extent of the rocks is not fully known but they have been recognized with their fossils 20 miles (36 km.) to the northeast on the Grand Cascapedia river, and there is evidence that there they lie above marine deposits with a lower Middle Devonian fauna. The fish beds are thus, in a broad sense, "Old Red-sandstone."

The ferry from Dalhousie stops at Maguasha Landing. Maguasha point lies 2 miles (3·6 km.) to the east. Scaumenac bay covers the coast line from Maguasha point to High cape at the west—3 miles (5·4 km.). Westward from the ferry landing along the shore, are exposures of very interesting and suggestive boulder beds, loosely cemented, interlaminated with sand layers, all lying beneath the fish-bearing strata. These boulders are largely limestone, freely containing fossils which are for the most part of normal marine Lower Devonian age. No fossils of later date than this age have been observed in them. There is no evidence of unconformity between them and the overlying beds.

The fish beds stand in high cliffs reaching 100 feet (30m.) or more in places and are essentially grey sand-shales and sandstones. The fish remains occur in the nodules and concretions, and in blocky parts of the shale beds. These beds afford the most abundant and some of the best preserved fish remains of the Devonian, although the genera and species are few. *Bothriolepis canadensis* is the most profuse in specimens and the extraordinary restorations by Patten are based on material obtained here. *Scaumenacia curta* is not uncommon in almost complete examples in the nodules. *Eusthenopteron foordi* often attains a size of 2-3 feet, and occurs in the shale layers. *Coccosteus canadensis* and *Acanthodes concinnus* are also among the commoner species. Other members of this fish fauna are *Cephalaspis laticeps*, *Euphanerops longaevus*,

*See Map,—Scaumenac Bay, Quebec.



Patten's restorations of *Bothriolepis canadensis* Whiteaves, from Scaumenac bay.

Diplacanthus striatus, *D. horridus*, *Holoptychius quebecensis* and *Cheirolepis canadensis*.

Intermingled with the fish remains are excellent examples of Devonian ferns which have been described by Sir Wm. Dawson.

BIBLIOGRAPHY.

Stratigraphy—

1. Ells, R. W.......... Report Geological Survey of Canada. 1880–82.

2. Clarke, John M...... N.Y. State Museum, Rep't Director 1911.

Fossils—

3. Whiteaves, J. F...... American Journal of Science 1880, v. 30.

4. Whiteaves, J. F...... Canadian Naturalist, 1881, v. 10.

5. Whiteaves, J. F...... Royal Society of Canada. Trans. v. 4, s. 4, 1887.

6. Whiteaves, J. F...... Royal Society of Canada. Trans. v. 6. s. 4, 1889.

7. Woodward, A. Smith. Geological Magazine. 1892.

8. Woodward, A. Smith. Outlines of Vertebrate Paleontology.

9. Traquair, R. H...... Fishes of the Old Red Sandstone: Monogr. Palaeontogr. Society, 1904.

10. Eastman, Charles R. Devonic Fishes of the New York Formations. N.Y. State Museum Mem. 10, 1907.

11. Patten, William.... The Evolution of the Vertebrates and their Kin. 1912, p. 368.

12. Hussakof, L........ Notes on Devonic Fishes from Scaumenac Bay: N.Y. State Mus. Rep't. Director 1912.

DALHOUSIE.*

South of the village of Dalhousie (1·5 m.) is Dalhousie mountain, an intrusive mass, partly rhyolitic, from which depart, toward the east, apophyses of diabase, varying in width. The water front of the village and the rocky islets skirting it belong to the northernmost and broadest of

*See Map—Dalhousie.

these volcanic arms (*Apophysis 1*). From the station eastward to Inch Arran point and light (1·5 miles) the shore cliffs are entirely of this rock, and on the Inch Arran cliff there are conspicuous inclusions of crystalline rocks surrounded by radial fracture and shrinkage lines. From Inch Arran (at low tide) along the shore past the Bon Ami islets and the "Gateway", the diabase of this apophysis continues to Stewart's or Fossil cove.

The Devonian section of Stewart's cove extends along a sea frontage of 1,700 feet (510 m.), but is divided by *Apophysis* 2, which has a 900 foot (280 m.) section. The fossiliferous strata are bounded on the south by *Apophysis* 3, and the actual exposed thickness of these sediments is about 430 feet (130 m.). The rocks are soft calcareous shales with thin limestone bands, thicker toward the top and hardened at contact with the diabase (*see* contact between shales and *Apophysis 2*). The strata have a uniform dip of 70°-75° N.E.

Apophysis 1 lies above these beds, but their contact is buried under the beach sand.

The highest beds are, beginning at the north:

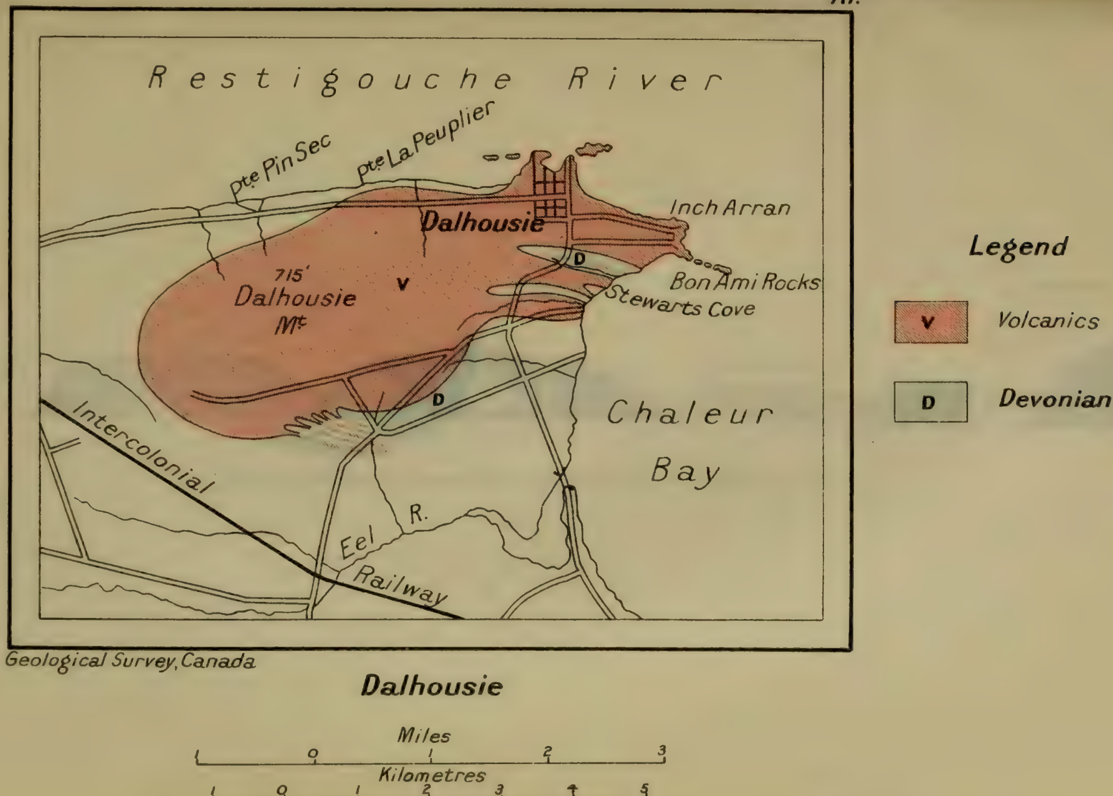
1 Coral limestones with very abundant and diverse *Favosites;* also *Zaphrentis* and *Halysites*......	25 ft. (8 m..)
2. Barren shales..............................	15 " (4·5 m.)
3. *Ash beds* with *Rensselaeria stewarti*.............	1 " (·3 m.)
4. Calcareous shale with gastropods (Coelidium)..	2 " (·6 m.)
5. *Ash beds* alternating with thin limestones and shales all highly fossiliferous. Ash beds with *R. stewarti*.............................	30 " (9 m.)
6. Soft shales with lamellibranchs................	10 " (3 m.)
7. Thin limestones and soft shales profuse in corals and brachiopods.........................	95 " (29 m.)

Apophysis 2. In the middle of this is a detached mass of hardened glazed Devonian shale 30 by 15 feet (9 by 4·5 m.), at an angle to the normal dip; then follow from the south end of the volcanics downward:—

8. Compact limestone.........................	10 " (3 m.)
9. Coarse *ash bed*	12 " (3·6 m.)
10. Impure limestone with shale..................	165 " (50 m.)
11. Calcareous shale with *Sieberella pseudogaleata* and corals.................................	30 " (9 m.)

A fauna of 80 species has been described and illustrated from these beds by Clarke and their vertical range through

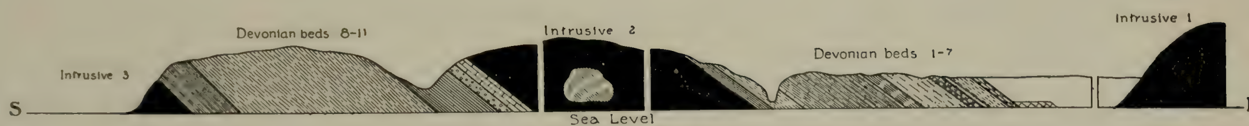
A1.



Geological Survey, Canada

Dalhousie

Excursion A 1.



Section of the marine Devonian strata, Stewart's Cove, Dalhousie N.B.

the section plotted. The fauna is rich in turrillated gastropods of the genera *Melissosoa* and *Coelidium*, lamellibranchs of the genera *Pterinea*, *Pteronitella*, *Mytilarca*, *Carydium*, *Palaeoneilo* and very profuse in the brachiopods *Leptaena*, *Stropheodonta*, *Strophonella*, *Spirifer*, *Leptaenisca*, *Orthis*, all of Helderberg species and types, and Rensselaeria of widespread early Devonian aspect. The beds are regarded as equivalent in fauna with the Helderberg of New York and the sea which deposited them, to have had direct connection with the interior Appalachian sea by one of several well defined Devonian sea ways parallel to the Appalachian axes. This channel or trough carried a very different assemblage of Helderberg species than the contemporary channel (St. Alban) in northern Gaspe (see p. 92).

Two miles southwest from this exposure, along the Eel River road and closer to the body of the volcanic mass is a second section of these sediments, 200 feet in length, in which are 5 interbedded deposits of volcanic tuff and ashes, in part carrying fossils.

BIBLIOGRAPHY.

1. Ells, R. W. . . . . Geological Survey of Canada, 1879–80.
2. Ells, R. W. . . . . Report on Geology of Northern and Eastern New Brunswick with map New Brunswick sheet 3 S.W. 1880–82.
3. Dawson, J. W. . . . . . . Acadian Geology, 1891, p. 578.
4. Billings, E. . . . . (List of fossils, *idem*).
5. Lambe, L. M . . . . Contributions to Canadian Paleontology, v. 4, 1901.
6. Ami, H. M . . . . Equisse Gèol. du Canada, 1902.
7. Clarke, John M. . . . . . The Dalhousie Formation: New York State Museum Mem. IX, pt. 2, 1909, p. 1–51, pls. 1–11.
8. Clarke, John M. . . . . . Eruptive Contacts in the Marine Devonic Dalhousie beds: N.Y. State Museum, Rept. Director, 1911, p. 125–128.

CHALEUR BAY.

PHYSIOGRAPHIC NOTE.

(J. W. Goldthwait.)

Chaleur bay, like the smaller Miramichi on the south and the greater St. Lawrence on the north, is a broad river valley which has been deeply drowned beneath the sea. At its head, west of Campbellton, it narrows to a slender point, into which the Restigouche and Matapedia rivers discharge. Similar sharp re-entrants or tributary estuaries lie at the mouth of its other large branches, the Nipisiguit at Bathurst and the Nouvelle and Cascapedia rivers on the north side. The drowning seems to have taken place during the Pleistocene period.

In this narrower upper portion of Chaleur bay evidences of submergence seem nowhere to extend above 50 feet (15·2 m.). Apparently the ice sheet lingered longer here than over the coast beyond Bathurst, covering the ground during the greater part of the stage of post-Glacial submergence. In no other way does it seem possible to explain the complete absence of elevated beaches like those at Bathurst (195 feet or 59·5 m.) and the presence in their place, in the zone below 200 feet, of kames whose sides appear to be too steep to have been covered by the sea for even a short time since the ice sheet released them from its grasp.

According to Chalmers, the striae and direction in which boulders and till have been transported indicate that the ice which mantled the country around Chaleur bay during the Glacial period moved radially into it from the north, west and south, forming a local, estuarine glacier. In the later stages the ice seems still to have pushed down from the high interior of Gaspe through such valleys as the Cascapedia and Nouvelle, after it had disappeared as a sheet from the coast. The kames of the north shore of the bay, which lie unmodified on ground within the 200-foot limit, seem to demand this.

On the way from Campbellton to Bathurst the railway skirts the shore of the bay, affording distant views of the rugged plateau of the Gaspe peninsula. A mile beyond Nash creek it reaches the eastern end of the great Restigouche kame, a fairly continuous ridge which extends

nearly 12 miles (19 km.) along the shore. The track crosses it east of New Mills station. Like other kames of the upper part of Chaleur bay, and of its tributaries the Nouvelle and Cascapedia, this appears to be a river deposit, formed within or against the ice during the withdrawal of the glacier from the coast. The Restigouche kame is 175 feet (53·3 m.) high at its west end and 50 feet (15·2 m.) high at the east end. As would be expected, it is overlapped by the fossiliferous marine clays which register post-Glacial submergence.

Along the north shore of Chaleur bay not a sign ot wave-built beach or of wave-cut cliff appears above 75 feet (22·8 m.) although the opportunity for them is the best. Here and there faint beach ridges are to be seen below the 75-foot mark, and at New Richmond marine fossils have been collected from clays and sands which reach up to 40 feet (12·2 m.). At no place, however, have shells been reported from altitudes as high as those on the south side of the bay. All the way along the shore from Chaleur bay around to Cape Gaspe the sea is trimming back fresh cliffs into the land. While there is nothing extraordinary about this in itself, it becomes important when this shore is compared with that of the St. Lawrence just around the end of Gaspe where a shelf 20 feet (6·1 m.) above the sea extends for three or four hundred miles along the coast recording a recent elevation of 20 feet. Around on the south side of the Gaspe peninsula the recent movement if any, must have been a subsidence, slowly deepening the water on the shelf, and facilitating the attack of the sea against the cliffs.

ANNOTATED GUIDE.

DALHOUSIE JUNCTION TO NIPISGUIT JUNCTION.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

Dalhousie Junction—Alt. 79 ft. (24 km.). From Dalhousie Junction to Bathurst, the Intercolonial railway closely follows the southern shore of the Bay of Chaleur. Throughout nearly the whole distance the bold front of the Gaspe highlands are visible rising

Miles and Kilometres.

steeply from the north side of Chaleur bay to heights of from 1,000 feet to 1,500 feet (300 m. to 450 m.) above the sea.

The southern coast of the Bay of Chaleur from Dalhousie eastward is low. Inland the country rises very evenly and attains elevations of between 600 feet and 900 feet (180 m. and 275 m.) in a distance of between 5 miles and 10 miles (8 km. and 16 km.). Farther inland, altitudes of 2,000 feet (600 m.) or more are reached and in certain districts the country is very rugged.

As far eastward as Bathurst, the country to the south of Chaleur bay is mainly underlain by Silurian strata, in places richly fossiliferous. Lower Devonian measures probably occur, while near Bathurst there is a wide area of Ordovician. Various varieties of igneous rocks of plutonic and volcanic types are present. The measures in general are closely folded, in places crenulated, along axes pursuing courses that strike towards the northeast. The strata are also much faulted. Along the sea front is a very narrow, discontinuous fringe of the Bonaventure formation of early Carboniferous or possibly late Devonian age. The Bonaventure measures are flat-lying, almost wholly undisturbed. Their presence in a nearly undisturbed condition, on both sides of the Bay of Chaleur, apparently indicates that this wide, shallow depression originated in Devonian time.

Leaving Dalhousie Junction the railway runs through a low, wide valley underlain by the horizontal red conglomerates and sandstones of the Bonaventure formation. On the north side rise the ridges of basic rocks forming Dalhousie mountain.

The railway presently approaches close to the coast. The narrow fringe of Bonaventure beds continue for about one mile past Charlo.

9·9 m. **Charlo Station**—Alt. 53 ft. (16·1 m.). Be-
16·3 km. yond Charlo for a distance of about 12 miles (19 km.), the railway traverses a zone in which Silurian sedimentary strata alternate with areas

Miles and Kilometres.

of basic igneous rocks. The Bonaventure measures are absent from the shore but form Heron island which lies a few miles east of Charlo. Approaching Nash creek, the low, red cliffs of the eastern end of Heron island are visible.

22·0 m.
35·4 km.

Nash Creek Station—A mile beyond Nash Creek, the Bonaventure strata outcrop on the shore and extend eastward along it for 15 miles (24 km.).

25·0 m.
41·1 km.

Jacquet River Station—Alt. 55 ft. (16·8 m.). A long narrow band of red 'felsites' (rhyolites?) extends inland from Jacquet river. The igneous rocks have been supposed to be of Pre-Cambrian age. Possibly the felsites are of Silurian or Devonian age as in the case of similar bodies occurring elsewhere in the great Siluro-Devonian area of northwestern New Brunswick.

To the east of Belledune river, 9 miles (14·5 km.) east of Jacquet river, the railway traverses a zone of black slates of late Silurian (Guelph?) age. Along the coast are outcrops of fossiliferous red, grey and black limestones with shales of various colours, and sandstones and conglomerates. These measures range in age from Clinton to Niagara and, possibly, Guelph. They are underlain by red shales, sandstones and conglomerates with a thickness as great as 1,000 feet (300 m.) or more. The total thickness of the Silurian beds is large but the strata are so closely folded and so much faulted that no reliable estimate of total thickness may be made.

34·4 m.
55·4 km.

Belledune Station—Alt. 84 ft. (25·6 m.). After passing Belledune station, the railway traverses a circumscribed area of igneous and altered sedimentary strata. Igneous rocks are exposed in a number of rock cuts and two long cuttings occur in them on both sides of Elmtree river, 6½ miles (10·5 km.) beyond Belledune. The igneous rocks include granite and diabase. The different varieties of igneous rock and the sedimentary strata which are possibly in part

Miles and Kilometres.

of Silurian, in part of Ordovician age, are intricately associated. In places gneissic rocks have developed apparently as the result of lit par lit injection of granite material into sedimentary beds.

Beyond the crossing of Elmtree river, the railway pursues a southerly course and traverses a band of closely folded Silurian measures. The Silurian strata are succeeded on the south by Ordovician beds; the line of contact passing westward just south of Nigadu river, $4\frac{1}{2}$ miles (7·2 km.) from Elmtree river. In the northern part of the Ordovician area, the measures are light coloured slates, sandstones and fine conglomerates possibly of tuffaceous origin. They are closely folded along east-west axes and are cut by numerous dykes of diabase. At one locality north of the crossing of Tetagouche river, the railway crosses an area of igneous rocks possibly including both tuffs and lavas.

51 m. 82·1 km. **Tetagouche River**—At the crossing of Tetagouche river are deep cuts in stratified sands and clays containing many shells such as characterize the Leda clay and Saxicava sands of the St. Lawrence valley. These unconsolidated, stratified deposits have a thickness of at least 100 feet (30 m.) and probably are much thicker.

Along the Tetagouche river at the railway crossing, occur black slates carrying a graptolite fauna of lower Trenton, (Normanskill) age. These black slates with associated beds of fine sandstone form a wide zone of closely folded strata stretching inland in a westerly direction.

54 m. 86·9 km. **Bathurst Station**—Alt. 45 ft. (13·7 m.). At Bathurst the railway leaves the coast. The town of Bathurst is visible from the railway. It is situated at the foot of the nearly landlocked bay into which empties the Nipisiguit river, one of the larger rivers of New Brunswick.

Leaving Bathurst station, the railway follows along the west bank of Little river. At the crossing of a large tributary and again farther

Miles and Kilometres.

south at the crossing of Little river, are exposures of biotite granite belonging to a large body which cuts and highly alters the surrounding Ordovician strata. The granites occupy an area of about 80 square miles; the granite body is presumably of much greater area than this since its eastern portion is hidden by a mantle of younger, Carboniferous strata.

57·4 m. 92·4 km. **Nipisiguit Junction.**

ANNOTATED GUIDE.

NIPISIGUIT JUNCTION TO BATHURST MINES.

(G. A. Young.)

57·4 m. 92·4 km. **Nipisiguit Junction**—From Nipisiguit Junction the Northern New Brunswick and Seaboard railway runs southward up the valley of Nipisiguit river to Bathurst Mines distant about 17 miles (27·3 km.). The railroad for most of the distance, passes through the forest out of sight of the river. Along the river exposures of granite continue for a distance of about 6 miles (9·6 km.). From the southern boundary of the granite batholith to near the Great Falls on the Nipisiguit river, the exposed strata are apparently of Ordovician age—bands of dark slates like those on the Tetagouche river alternating with others of green, probably tuffaceous, rocks. The strata are closely folded and much faulted.

At about the fourteenth mile the wide stream bed of the Nipisiguit river is visible from the railway. About a mile farther, the gorge of the river below the Great Falls, comes into view. The lower portion of the gorge has been cut through black slates dipping upstream at high angles. The upper portion of the gorge is in quartz porphyry overlying the dark slates. At about the sixteenth mile, the crest of the falls may be seen from the railway, and from this point to Bathurst Mines the railroad passes close to the river edge through many cuttings in sheared quartz porphyry.

BATHURST MINES.*

(G. A. Young.)

The iron ore deposits of Bathurst Mines occur in three main bodies or groups of bodies, the longer axes of which, at the surface run about north and south. These deposits occur within a limited area on the northern bank of Nipisiguit river and in the vicinity of Austin brook, a southeasterly flowing tributary of the main river. One of the groups of iron ore bodies known as No. 2 deposit, outcrops on the northeast side of Austin brook valley and extends northward for at least 1,200 feet (360 m.). Another ore body, known as No. 1 deposit, outcrops on the southwest side of Austin brook valley about 900 feet (275 m.) west of No. 2 deposit and extends southerly for several thousand feet. The third group of ore bodies known as No. 3 deposit, lies nearly due north of No. 1 body at a distance of about 800 yards (730 m.).

In the immediate neighbourhood of the ore bodies, all the rocks are of igneous origin and belong to three main types, namely, quartz-free porphyry, quartz porphyry and diabase. The rocks in the district are largely covered by drift and therefore the relationships existing between the different rock varieties has not been established, but it is assumed that the quartz-free porphyry and the quartz porphyry are closely related in origin and age and that the diabase occurs in dyke or sill-like bodies cutting the porphyries.

The quartz-free porphyry outcrops in the eastern and southwestern portion of the area; the quartz porphyry forms the central portion of the area; and the diabase occurs in the western portion. No. 2 deposit lies within and just along the boundary between the area of quartz-free porphyry on the east and the central zone of quartz porphyry; No. 1 and No. 3 deposits occur along the western margin of the zone of quartz porphyry near the area occupied jointly by diabase and quartz-free porphyry.

The quartz-free porphyry is usually of a dark greyish colour, is fine grained, dense, and contains very small phenocrysts of plagioclase feldspar. In most cases the rock has at least an irregular schistose parting and in many

*See Map, Bathurst Iron Mine.

places has been sheared to a glistening or dull, sericite or chlorite schist.

The quartz porphyry varies in colour from very dark grey to light greenish grey, the lighter colours being characteristic of the more schistose varieties which grade into sericite schists. The rock, where not too much sheared, is crowded with crystal fragments of glassy quartz, white orthoclase and acid plagioclase feldspar.

The diabase is finely granular, in some cases nearly black in colour; in others pale greenish and then has a pronounced schistosity.

The ore has generally a prominent slaty cleavage, is fine grained, and is composed largely of finely granular magnetite with a variable amount of hematite. Slight variations in grain are visible along regularly alternating bands. The banding varies in degree from microscopic to very broadly developed, being indicated where coarse by the occurrence of various impurities distributed along bands. The ore has a general black colour, tinged greyish from the presence of minute grains of quartz and feldspar which in some bands are finely and uniformly disseminated, while in other cases they occur in lines, narrow streaks and lenticular areas. Considerable pyrite is present and tends to occur in large and small, elongated, lenticular aggregates. Quartz is relatively abundant occurring in veins and stringers. A large number of analyses indicate that the iron content of the ore ranges from 39·6 per cent to 58·7 per cent; sulphur from 0·009 per cent to 0·27 per cent; and, phosphorus from 0·385 per cent to 1·222 per cent.

Examined in thin sections under the microscope, the ore is seen to be composed of minute, rapidly alternating bands of nearly pure iron ore, or of iron ore with considerable finely granular quartz and feldspar; and other bands of nearly pure quartz, with varying proportions of feldspar, iron ore, etc.

In the case of No. 2 body, a portion of its southern end, and of the east and west walls is visible. The greatest width of the body where stripped, is a little over 40 feet (12 m.). The containing walls are sharply defined, and the body appears to dip to the west at angles varying between 60° and 80°. The ore is banded and some quartz is present in comparatively large, irregular veins. Little or no pyrite is to be seen except immediately along the walls.

On the hanging wall-side, at a distance of about 150 feet (45 m.) from the ore, ordinary schistose quartz porphyry crowded with phenocrysts of quartz and feldspar is visible. At exposures intermediate between this and the ore body, the rock gradually assumes a more schistose habit. On the foot-wall side an analogous set of phenomena is visible but the rock there appears to be a quartz-free porphyry.

The southern termination of the ore body has been laid bare. The mass of ore ends in a number of angular, finger-like projections extending a few feet into the country rock and associated with considerable quartz.

In the case of No. 1 deposit, the foot-wall is exposed for a short distance. The rock, probably a much altered, schistose quartz porphyry, is very heavily charged with pyrite. It has a pronounced schistose parting along which

Bathurst Iron mine. No. 1 orebody. August, 1912.

occur seams and veins of quartz. The boundary of the ore body is remarkably sharp. The ore seems to end abruptly along the plane corresponding to that of the slaty parting and banding in the ore, and of the schistose parting in the wall rocks.

The ore bodies have the form of abruptly terminating beds or bands, with, in each case, a fairly constant thickness. The walls where seen, are always sharply defined and dip

westward at angles varying from 45° to nearly 90°. In the case of No. 1 deposit, the ore body at its outcrop at the northern end has a thickness of 105 feet (32 m.). In a drill hole which intersected the body at a vertical depth of 410 feet (125 m.), the ore body had a thickness of 65 feet (19·8 m.). As indicated by the results obtained from a magnetometric survey, the ore body has a length of about 2,000 feet (610 m.).

It is believed, for the following reasons, that the ore bodies have formed through the partial replacement of schistose quartz porphyry by iron ore, along sharply defined zones.

The prominent banding of the ore, sometimes on a coarse scale, sometimes microscopic in its fineness, is, when seen in thin sections under the microscope, very regular, and gives the impression of being an original structure, not a secondary one imparted in some way to the ore after its formation.

The parallelism of the banding of the ore (seemingly an original structure) and its attendant slaty cleavage, with the walls of the ore bodies and with the planes of schistosity in the neighbouring rocks, forcibly suggests that the ore has replaced a schistose rock, and has partly preserved the original schistose structure.

The finely granular quartz present throughout the ore, as well as the less abundant granular feldspar, may readily be regarded as representing original constituents of the replaced, schistose rock, possibly sheared quartz porphyry. That the original rock was schistose is supported by the fact that in all cases where observations were possible the country rock, as it neared the ore bodies, was found to be progressively more schistose.

Under the above hypothesis, the occasional narrow bands of dark green schist seen in No. 1 body may represent a rock variety that more strongly resisted the replacing action of the ore bearing solutions. The apparently basic composition of these bands, and the occurrence of schistose diabase along the western walls of the ore body, suggest that they may represent dykes of diabase.

As regards the quartz veins, in the case of a thin section of ore charged with small reticulated and crenulated quartz veins, it was seen that the alternating microscopically fine lines and extremely narrow bands of quartz, quartz impregnated with iron ore, and nearly pure iron ore,

conformed as nearly as possible to the intricate folding exhibited by the quartz veins. On the assumption that the ore and its structure are due to the replacement of schistose rock, the minutely corrugated forms exhibited by the ore represent a corrugated structure previously existing in the now replaced schist.

The appearance of the ore in thin section did not seem to indicate that the ore would fracture along the old corrugation planes, and so permit the formation of later quartz veins following similar crenulated courses, and, therefore, it is concluded that the veins did not originate after the formation of the ore.

The appearance in the thin sections of the bands or zones of quartz veins, and of the ore body as a whole, does not warrant any supposition that the quartz veins were bent after the formation of the ore.

It is true that the veins might have been formed contemporaneously with the ore, but, on the other hand, the puckering and bending of the veins in the ore are duplicated over a part of the exposures of country rock on the foot-wall of No. 1 body. This would indicate that the original rock had been twisted and bent, that quartz veins were introduced either before, during, or after the folding, and that after this the rock had been replaced by ore that still retains many indications of the original crenulations, as well as many or all of the quartz veins.

BIBLIOGRAPHY.

1. Hardman, J. E...... A New Iron Ore Field in the Province of New Brunswick; Jour. Can. Mining Inst , Vol. II, pp. 156–164, 1908.

2. Lindeman, E........ Map—Magnetic Survey, Austin Brook, Dept. of Mines, Mines Branch.

3. Young, G. A........ Geological Survey Canada, Memoir No. 18.

NIPISIGUIT JUNCTION TO HALIFAX.

(G. A. YOUNG.)

Miles and Kilometres.

0 m. 0 km. **Nipisiguit Junction.** — The Intercolonial railway about one half mile beyond Nipisiguit Junction, crosses Nipisiguit river and enters the great Carboniferous area of New Brunswick. Nearly the whole eastern half of the province, an area of about 10,000 square miles (26,000 sq. km.), is floored by Carboniferous measures. The strata are mainly grey sandstones, and red and grey sandstones and shales, of Millstone Grit (Pottsville) age. The measures over the greater part of the area are nearly horizontal and the land surface is very even, scarcely rising anywhere higher than 500 feet (150 m.) above the sea.

118·9 m. 191·3 km. **Moncton.**—Alt. 50 ft. (15 m.). Moncton is situated near the southern border of the New Brunswick Carboniferous area, the boundary being formed by a series of highlands extending along the coast of the Bay of Fundy. These highlands are underlain by deformed Pre-Cambrian and early Palæozoic strata associated with great volumes of igneous rocks. Along the southern margin of the Carboniferous area, older divisions of the Carboniferous are exposed in a folded and faulted condition.

Leaving Moncton the railway for some distance passes through a district of Carboniferous strata, in part disturbed, which extend eastward around the northeastern end of the upland of deformed Pre-Cambrian and Palæozoic rocks. After traversing this district, the railway crosses the low-lying Chignecto isthmus which connects New Brunswick with the peninsula of Nova Scotia. The isthmus is underlain by Millstone Grit strata and measures of late Carboniferous or Permian age. The strata lie in wide open folds.

Miles and Kilometres.

After crossing Chignecto isthmus the railway enters the low-lying portion of Nova Scotia which extends for many miles along the Gulf of St. Lawrence coast and reaches inland to the Cobequid hills. This low-lying region is floored with various divisions of the Carboniferous and also with strata of Permian age. The measures in places are closely folded and faulted while in other places they lie nearly horizontally or in simple open folds.

About 100 miles (160 km.) beyond Moncton, the railway crosses the Cobequid hills. This upland extends eastward from the head of the Bay of Fundy for 100 miles (160 km.). The highlands in places rise to heights of about 1,000 feet (300 m.) and are crossed by the railway through a pass having a summit elevation of 615 feet (188 m.). They are formed, in the main, of a complex assemblage of plutonic rocks, both acid and basic, and various schists. Along the southern margin of the area, strata of about mid-Carboniferous age are cut and altered by igneous rocks. Whether all the igneous rocks of the Cobequids are of post-mid Carboniferous age is unknown.

After crossing the Cobequids, the railway passes through a zone of disturbed Carboniferous beds flanking the Cobequids on the south, and then enters the low lying Triassic area which in part encircles the head of the Bay of Minas. This arm of the sea is an eastward projection from the Bay of Fundy.

310·2 m. **Truro.**—Alt. 60 ft. (18·3 m.). Truro stands
499·2 km. in the low-lying Triassic area at the head of the Bay of Minas. The Triassic measures are largely red sandstones and shales and are flat-lying.

Leaving Truro the railway for a few miles runs over the low Triassic area, after which it turns south and by means of a low divide, crosses the highland area which extends for 250 miles (400 km.) in a northeast-southwest direction and which forms the axis of the Nova

Miles and Kilometres.

Scotian peninsula. The highlands rise to a general elevation of between 700 and 1,000 feet (215 and 300 m.) above the sea, but in the low, very wide pass traversed by the railway, the summit elevation is only 141 feet (32 m.).

After leaving the low-lying Triassic area in the neighbourhood of Truro, the railway first traverses a district underlain by Carboniferous, perhaps in part Devonian, strata belonging to the horizon of the Union-Riversdale group and the Windsor series. Beyond this area, the railway enters the belt of Pre-Cambrian strata (the Goldbearing series), which with intrusive bodies of Devonian granite, stretch the whole length of the Atlantic seaboard of Nova Scotia. The Goldbearing series consists of about 35,000 feet (10,600 m.) of quartzites and slates; the quartzites are more abundant in the lower portion of the series while the slates predominate in the upper portion. The strata lie in large and small dome-shaped folds which occur along axial lines that in a general way strike northeast-southwest.

372 m.
597·1 km.

Halifax.—Halifax is the capital of the province of Nova Scotia. The city is situated on the western side of one of the numerous fiords that characterize the Atlantic coast of the province. The major portion of the city is underlain by dark slates of the upper division of the Goldbearing series. The strata are folded along axes striking about south-southwest. The northern end of the city and the country to the north are underlain by the lower quartzite division arranged in a series of folds parallel to those in the slate division. A short distance west of the city the sediments are bounded by a batholith of granite. Along the granite contact the slates have been highly metamorphosed, but they retain their normal dip and strike. Absence of any local disturbances of the strata due to the granite intrusions is characteristic of the whole area of the Goldbearing series.

ANNOTATED GUIDE

Halifax to Windsor.

(G. A. Young.)

Miles and Kilometres.

0 m. 0 km. **Halifax.** Leaving Halifax station, the Intercolonial railway passes rock cuttings in dark slates of the upper division of the Goldbearing series. The strata dip to the southeast at angles of from 20° to 65°. In a short distance the railway closely approaches the shore of the narrows connecting Halifax harbour with Bedford basin, and enters an area underlain by the lower quartzite division of the Goldbearing series. The strata dip regularly to the southwest at angles of between 50° and 80° and are exposed in rock cuttings along the railway.

4 0m. 6·4 km. **Rockingham Station.** One mile past Rockingham, at Birch cove, an anticlinal axis in the quartzites is crossed. On the north side of the axis, the strata, (exposed in numerous cuts), dip to the northwest at angles varying between 20° and 45°

Two miles farther, at Mill cove, a synclinal axis is crossed.

8.6 m. 13·8 km. **Bedford Station.** Bedford is at the head of the inlet along whose shores the railway follows from Halifax. The depression of the inlet is continued inland by a valley bounded by hills rising to heights of 200 to 400 feet (60 to 120 m.). The railway crosses this valley and enters a low, rough, hilly country with many small, irregular lakes lying at various elevations up to 300 feet (90 m.) and more, above the sea.

Numerous rock cuttings in quartzites occur along the railway, the strata dipping to the southeast at angles of from 20° to 40°.

Two and one quarter miles (3.6 m.) beyond Bedford a low height of land with an elevation of 140 feet (42·6 m.) is crossed. The waters on the northern side of this divide drain northward to the Bay of Minas.

Miles and Kilometres.

One mile (1.6 km.) beyond where the railway crosses a small lake, the railway crosses an anticlinal axis. The Waverly gold district is situated on this anticlinal, one half mile to the east of the railway.

13·9 m.
22·4 km.
Windsor Junction. Alt. 129 ft. (36·8 m.). The Canadian Pacific railway joins the Intercolonial railway at Windsor Junction. At a distance of about 1 mile (1.6 km.) from the junction, the Canadian Pacific railway enters a zone of dark slates belonging to the upper division of the Goldbearing series. The belt has a width of about $3\frac{1}{2}$ miles (5.6 km.) and in it the strata lie in two synclinal folds. On the northwest side of this belt of slates, the lower strata of the quartzite division again outcrop. The boundary between the two divisions crosses Fenerty lake—a long narrow lake along whose southeast shore the railway runs for some distance.

The band of quartzites has a width of $4\frac{3}{4}$ miles (7.6 km.). The strata lie in the form of an anticline whose axis strikes N.E—S.W. The measures in general dip at angles of from 50° to 65°. Leaving Fenerty lake whose waters are about 250 feet (76.1 m.) above the sea, the railway climbs to a height of 456 feet (139 m.) and recrosses the height of land separating the waters draining southeast to the Atlantic from those draining northwest to the Bay of Minas.

Three quarters of a mile (1.1 km.) beyond the crossing of the height of land, the railway enters South Uniacke gold district which is located on an anticlinal dome near the northwestern border of the quartzite belt.

23·7 m.
38·1 km.
South Uniacke Station. Alt. 449 ft. (13·4.) South Uniacke station is close to the border of the quartzite belt. Beyond South Uniacke the railway crosses a belt of slates, $1\frac{1}{2}$ miles (2.4 km.) wide. The strata lie in two synclinal folds: the lower quartzite division is exposed in places along the intervening anticline.

Miles and Kilometres.

The railway passes along the western side of a small lake lying on the northwestern border of the slate belt. Beyond this point the railway enters a belt of the quartzite division and the strata are exposed in many rock cuttings.

26·8 m. 43·1 km. **Mount Uniacke Station**. Alt. 509 ft. (155 km.). After passing a number of rock cuttings in the quartzite, or lower division of the Goldbearing series, the railway runs for some distance along the southern shore of a lake. This lake lies on the contact between the Goldbearing series and a large batholith of granite which extends for 100 miles (160 km.) to the southwest and occupies an area of, approximately, 3,000 square miles (7,800 sq. km.). This granite intrusion is of Devonian age. Rock cuts in the granite occur along the railway. A short distance farther, after passing the northern end of a lake, the railway traverses for about ½ mile (0.8 km.) a small area of quartzites entirely surrounded by granite. Beyond this for a distance of 1½ miles (2.5 km.) the railway passes through an area entirely underlain by granite. In the succeeding 1½ miles, (2.5 km.), the railway follows along the curving northern boundary between the granite and the bordering strata of the Goldbearing series. Finally passing away from the granite region, the railway recrosses the height of land (altitude of crossing, 412 ft. (125.1 m.) and begins to rapidly descend along a valley to the more even, lower country visible to the north. The rock cuttings at first are in quartzite while farther on they are in dark slates. The strata of the Goldbearing series occur in regular, parallel folds which are truncated by the granite batholith.

36·8 m. 59·2 km. **Ellerhouse Station**—Alt. 258 ft. (78·6 m.). Beyond Ellerhouse the railway traverses a belt of the quartzite, or lower division of the Goldbearing series. The strata are exposed in a number of rock cuttings and along the walls of the gorge of the St. Croix river where this stream is crossed by the railway. Three

Miles and Kilometres.

quarters of a mile (1·2 km.) beyond the St. Croix river, the railway enters a narrow belt of Carboniferous strata consisting of shales, sandstones and conglomerates which are correlated with the Horton series. The measures dip towards the north at comparatively low angles. They extend in an east and west direction for about 6 miles (9·6 km.) and are interposed between the Pre-Cambrian Goldbearing series with its intrusive Devonian granites and the limestone, shale, gypsum, etc., of the Windsor series (Mississippian) flooring the low county to the north.

39·8 m. 64·0 km. **Newport Station**—Alt. 119 ft. (36·3 m.). Newport is situated on the southern boundary of the comparatively low area of Windsor series which extends northwards for about 13 miles (20·9 km.) to the Bay of Minas. Before reaching Newport and after passing it, gypsum cliffs and quarry workings are visible. To the west and southwest is visible the front of the highland underlain by the Devonian granite and the Pre-Cambrian Goldbearing series. This highland rises abruptly from the bordering lowland of Carboniferous measures, to heights of 600 feet to 800 feet (180 m. to 240 m.) above the sea.

45·5 m. 73·2 km **Windsor**—Alt. 26 ft. (7·9 m.). The town of Windsor is situated on the east bank of Avon river where it joins St. Croix river.

WINDSOR—HORTON.*

(W. A. Bell.)

INTRODUCTION.

The district herewith described borders on representatives of three main physiographic divisions of the eastern provinces of Canada. These are as follows: (1) the pre-Carboniferous uplands, (2) the Carboniferous lowlands, and (3) the Bay of Fundy or Triassic lowland.

*See Map— Windsor—Horton Bluff.

The present geographical location of these divisions is due primarily to Palæozoic constructive and mountain-making processes, as expressed in deposition, folding, and faulting, and secondarily to Mesozoic, Tertiary and Quaternary destructive and epeirogenetic processes, as expressed in erosion and vertical warping. The deformative processes of Palæozoic time have determined the general northeasterly-southwesterly trend of the structural axes, while the differential vertical movements of post-Palæozoic time, working largely independently of structure, have controlled the present surface features.

CRETACEOUS AND TERTIARY PENEPLAINS.

The pre-Carboniferous uplands comprise the highlands of New Brunswick, the Cobequid hills, and the Southern upland or plateau of Nova Scotia. Daly [**1**] has furnished evidence to support the hypothesis that these surfaces represent remnants of a once continuous and more extensive Mesozoic peneplain. The age of the peneplanation was assigned by him to the Cretaceous by correlation with the New England and southern Appalachian land forms. The basic argument for this interpretation is the remarkable discordance of surface form with underlying structure. Vertical uplift and warping, accompanied by southeasterly tilting, in early Tertiary time exposed the old-age surface to renewed differential denudation, resulting finally in the sculpture of a local Tertiary base—a levelled surface on the softer Carboniferous rocks. But the ancient complex of more resistant rock still upholds large areas of the older or Cretaceous plain and so preserves the historical record of erosion.

TRIASSIC LOWLAND.

The history of the Triassic lowland, or Bay of Fundy region, is necessarily involved in that of the Carboniferous lowland, but is further complicated by the addition of tidal scour to subærial processes as an active though variable denuding agent, and by the fact that the processes of destruction worked on a peculiar type of constructional topography, apparently the resultant forms of monoclinal faulting [**2**], parallel to the older land areas. The modified result has its expression in such features as the trap ridge of North mountain.

SOUTHERN PLATEAU.

The particular area to be described is an embayment of the Carboniferous lowland bordering the Southern plateau to the south and west, but merging into the Triassic basin of the Bay of Fundy to the north. It is drained by the Avon river and its tributaries. The prominent characters of the three physiographic divisions may be read within the district. The Southern plateau is seen rising abruptly on the south to a smoothly curving, timbered skyline at an average elevation of about 500 feet (152·4 m.). This plateau is marked by a gently rolling old-age surface interrupted only by occasional residual hills rising several hundred feet above the general level of the plain, and by the narrow, young gorges of the northerly flowing streams. The irregular veneer of glacial debris has so modified the pre-Glacial drainage that abundant lakes as well as large areas of marsh are now present on the divides. The underlying rocks are a thick series of slates and quartzites, known as the Gold-bearing series, and generally assigned to the Pre-Cambrian; they are closely folded, and intruded by granitic masses. A plateau extension also limits the district on the west, but, whereas the descent to the lowland in the south is abrupt, here on the west it is eased by rolling foothills. In the former case the slope is from hard resistant rock to soft marls and gypsum, whilst in the latter a stronger development of the more competent Horton series intervenes.

NORTH MOUNTAIN.

An outlying remnant of this plateau surface forms the crest of the trap ridge of North mountain, which extends in a very even line a distance of some 120 miles (193 km.) at an average elevation of about 550 feet (167·6 m.). This ridge is uniformly carved on a sheet of massive, compact trap, roughly 200 feet (61 m.) thick, of which the lowermost bed is an amygdaloid conformable with Triassic red sandstone. To the south it terminates in an abrupt escarpment. To the north the dip is gently towards the bay.

CARBONIFEROUS LOWLAND.

The Carboniferous lowland, which in this area encroaches upon the upland in narrow embayments, is a portion of the Tertiary base-levelled plain. The mildly undulating surface is underlain here almost entirely by Lower Carboniferous (Mississippian) rocks. These are divided into two formations, the Horton, and the Windsor, whose relations to each other and to the Carboniferous elsewhere have been a matter of considerable discussion. The Horton includes a series of black, plant-bearing shales interbedded with quartzose sandstones and seemingly overlain by coarse arkose grits, sharp quartz sandstones and brick red shales. The supposedly overlying Windsor formation comprises a series of brick red and greenish marls, thick beds of anhydrite or gypsum and of dolomitic fossiliferous limestones. Post-Lower Carboniferous (Mississippian) folding and faulting have greatly deformed this soft yielding series, and good field sections are lacking.

ANNAPOLIS-CORNWALLIS VALLEY.

The Triassic lowland lies adjacent to the Horton beds on the north, forming the fertile Annapolis-Cornwallis valley. The slightly rolling surface nowhere rises high above sea-level. Along the shore of the estuary softly rounded divides alternate with fertile stretches of level marsh. The South Mountain plateau or the Horton foothills rises abruptly on the south, whereas the North Mountain escarpment limits the valley on the north. The underlying rock is mainly brick red sandstone, distinctly cross-bedded, in places coarsely conglomeratic, dipping at low angles to the north or northwest away from the highland. Its ferruginous but highly calcareous cement renders it especially susceptible to the attacks of the weather, resulting in a sandy red loam peculiarly adapted to the culture of fruits.

ANNOTATED GUIDE.

WINDSOR TO AVONPORT.

Miles and Kilometres.

0 m.
0 km. **Windsor.**—Alt. 26 ft. (7·9 m.). From Windsor, the Canadian Pacific railway runs west of north, cutting across the mouth of

Miles and Kilometres.

the Avon embayment of the Windsor series (Mississippian—Lower Carboniferous), This embayment extends up the basin of Avon river in a southwesterly direction into the Southern upland for a distance of about 5 miles (8 km.). Along the southern border the rocks underlying the Southern upland are largely granite and the rise to the upland is abrupt, but on the west the area of the Windsor series is limited by the Horton formation, which forms a belt of foothills of variable width, between the Windsor lowlands and a spur of the Southern upland.

The Windsor rocks are exposed in broken sections on the Avon river above and below the railway bridge.

5 m. 8 km. **Mount Denson Station**—Alt. 40 ft. (12·2 m.). Less than ½ mile (0·8 km.) north of Mount Denson station the railway approaches close to the shore and from here an outcrop of Windsor anhydrite may be seen at a low point known as Aberdeen beach. This rock is very different from the gypsum at Windsor, as it is massive, evenly bedded, less disturbed, and of a snowy-white colour. It lies in a low syncline succeeded to the south by a flat anticline.

The margin of the narrow Windsor embayment is crossed at this point, and the railway from here onwards, passes over a northeasterly trending area of Horton rocks which extend out from a spur of the Southern upland. To avoid the hills farther west, the railway clings closely to the shore. It is this projection or spur of the Horton strata that is cut transversely by the Avon river, thus exposing the Horton section.

11·9 m. 19·1 km. **Avonport Station**—Alt. 57 ft. (17·3 m.). Avonport is within 1 mile (1·6 km.) of the northern termination of the Horton spur or where the Horton rocks sink beneath the Triassic lowland of Cornwallis valley. A short distance east of the railway station the exposures of the Horton series commence on the banks of the mouth of Avon river.

HORTON BLUFFS SECTION.

GENERAL DESCRIPTION.

The Horton series, which here flanks the Southern plateau, is exposed for nearly 3 miles (5 km.) along the tidal estuary of Avon river in the section known as the Horton Bluffs.

Looking northwesterly from the Avondale shore, Cape Blomidon, the westerly termination of the Triassic trap ridge of North mountain, may be seen standing prominently about 500 feet (152 m.) above the sea. The contact of the trap with the underlying sandstone is there about 200 feet (61 m.) above the valley floor. The low country intervening between this picturesque ridge and Avonport is a part of the Annapolis-Cornwallis Triassic basin. The contact of the Triassic with the Horton shales is concealed on the shore, but the low red bluff ½ mile (0·8 km.) to the north is made up of heavily cross-bedded, wave-eaten, soft Triassic conglomerate of a dark grey or chocolate colour, consisting of well worn pebbles up to 4 inches or more in diameter of sandstone, red shale, quartzite and quartz, embedded in a matrix of subangular quartz grains, and bound by a ferruginous calcareous cement. The dips are gently northwestward.

The underlying Horton beds rest in a flat syncline, of which the northern limb is regular and moderately inclined, while the southern limb, though at first but slightly disturbed, becomes strongly folded and faulted against the succeeding arkose series. At the beginning of the section the black argillaceous or calcareous shales make up the low banks and pave the tidal flat in an overlapping series of broad plates. The average dip is here scarcely 7°. On numerous bedding planes abundant flakes of mica are conspicuous. Ripple marking is common; raindrop impressions may frequently be observed; and sun cracking is not at all rare. The most common fossils are the spore case of species of Lepidodendra, which are extremely abundant is some of the micaceous shales. *Lepidodendron corrugatum* Dn. and *Aneimites acadica*, Dn. the two most characteristic plants of the Horton, occur at various horizons, but they are nowhere abundant. A species of *Sphenopteris* is rather rare. In Dawson's collection occur in addition : *Lepidodendron aculeatum*, *L. sternbergi*, *L. dichotomum*, *L. elegans*,

L. tetragonum, *Strobila*, *Dadoxylon antiquum*, *Cordaites*, *Psilophyton plumula*, *Alethopteris lonchitica*, *Stigmaria*, and *Calamites undulatus*.

At the first prominent headland the beds are sharply flexed in the synclinal axis. Beyond, minor thrust slips render the dips more variable. A characteristic feature of these upper shale beds is the presence of large irregular septarian concretions. At the following headland there is a heavy channel deposit of sharp angular quartz sandstone, while about 150 yards (137 m.) beyond, there is an interesting horizon of Lepidodendra standing upright. Over thirty plants were counted within 10 yards (9 m.) of the section. They are all small in size, falling under 10 inches (25 cm.) in diameter, and the remains are now shale casts of the interior, all trace of the bark having disappeared. Just beyond the succeeding headland, perhaps 150 yards (137 m.) further, there are several bone beds, remarkable for the abundance of fish remains such as scales, spines, jaws, clavicles, and teeth. These are the remains of common elasmobranch and ganoid genera, such as *Strepsodus hardingi*, species of *Acanthodes*, and scales of *Elonichthys* and *Palœoniscus*.

The remainder of the section, where not concealed by drift, shows the strata in general maintaining their northerly dips but with frequent dislocation. Finally, however, the dips increase until the beds are standing almost vertically at the axis of a sharply closed anticline. Crumpling and faulting persist to the most important fault of the section, where the northerly dipping black shales abut against the southerly dipping grey arkose and brick-red shale. At other localities this arkose series is seemingly in conformity above the typical Horton, a fact which would indicate a downthrow here to the south. Similar arkose with interbedded shales carrying the Horton flora, occur in the brooks south of Windsor where it rests unconformably in steeply pitching contacts, on the pre-Carboniferous crystallines. A prominent feature of these beds, aside from their arkosic appearance and the chocolate colour of the shales, is the occurrence of channelling or local erosional unconformities between the sandstones and shales. From their highly disturbed condition near the fault, the beds soon resume a low northerly dip to the axis of a low anticline from which they dip gently southward beneath a heavy covering of drift. The next rock outcrop lies 3 miles

(4.8 km.) south exposing white, evenly-bedded anhydrite, probably belonging near the base of the Windsor, folded in a flat syncline with succeeding anticline, and striking S. 61° E. The average strike of the Horton beds is about S. 57° E.

The writer has made only a very rough estimate of the thickness of the Horton series. It is thought to be in the neighbourhood of 1,025 feet (312 m.) in the southern limb, while but 400 feet (122 m.) more or less is seen in the northern limb.

GEOLOGIC AGE OF THE HORTON SERIES.

The older geologists, Brown, [**7**] Jackson, Alger, and Gesner, [**8**] regarded the gypsum or Windsor series as equivalent in age to the New Red Sandstone, *i.e.* the Triassic. The Horton as a consequence, as well as from its plant remains, was thought to be a development of the Coal Measures. In 1842 Logan [**9**] visited the sections, and considered the Horton a phase of the gypsiferous series, assigning both to the Triassic. However, he submitted some of the Windsor fossils to de Verneuil and Count Keyserling who regarded them as identical with species from the Permian deposits of Russia, the Zechstein of Germany, or the Magnesian Limestone of England. Murchison [**10**] in his anniversary address to the Geological Society of London in 1843 also contributed to this view. However, Lyell's visit to the localities in 1843 initiated a new correlation. Fortified by both stratigraphical and palæontological evidence he announced the age of the gypsum formation as well as that of the Horton beds, to be Lower Carboniferous and therefore distinctly earlier than the overlying Productive Coal Measures. Of the Horton he writes: [**11** p. 209] "Both in the Windsor district and on the Shubenacadie, I found an intimate association between strata containing mountain limestone fossils, masses of gypsum, and coal grits, with Sigillaria and Lepidodendron, but no seams of pure coal in this part of the series." His general conclusions were abundantly verified by the work of Dawson [**3**, pp. 252–7]. The latter was, indeed, the first to give clear expression to the division of these beds into two distinct formations, naming what he considered the lower, the Horton series or Lower

Coal Measures, as differentiated from the overlying Windsor series. More recently, field geologists, especially Fletcher and Ells on structural and stratigraphic grounds, assigned much of Dawson's Carboniferous, including the Horton, to the Devonian. This reference gave rise to a discussion, not yet settled, which involves not only this series but the Riversdale and Union formations of Nova Scotia as well, and also the fern beds of St. John, New Brunswick. An interesting synopsis of the controversy was published by Fletcher in 1900 [**12**].

In later years the plants of these beds were submitted to Kidston of England and to David White of the U. S. Geological Survey, these two paleobotanists gave independent confirmation of the age of the Horton, Kidston [**13**] considering it was undoubtedly Lower Carboniferous, while White [**14**] stated that " the Horton plant terrane should, on purely paleobotanical grounds lie below the typical Carboniferous Limestone [Windsor series]; but I believe it should go hardly so low as the Ursa stage [uppermost Devonian], or below the boundary generally accepted for the Lower Carboniferous [Mississippian]". In comparison with the Mississippian beds of Pennsylvania and Virginia, Mr. White would place the Horton as nearly synchronous with the Pocono (Kinderhook). He also regarded it as the near equivalent of the Albert shales of New Brunswick and of the Calciferous Sandstone series of Scotland. A. Smith Woodward [**15**] has likewise pronounced on the Carboniferous age of the Horton fish remains, and finally L. M. Lambe, [**16**] who described the fauna of the Albert shales, has correlated these two series as quite, or nearly synchronous, and equivalent to the Calciferous Sandstone series as developed in Mid- and West Lothian and elsewhere in Scotland.

THE HORTON FLORA.

(David White.)

The Horton flora, like its probable contemporaries at the base of the Carboniferous in the Arctic regions of Alaska, Bear island, and Spitzbergen, and in Siberia, as well as in the Appalachian trough, is remarkable at once for its paucity in genera and species and for the great profusion of two or three very variable dominant plants. The fern-like plants, which probably are Cycadofilic, vary

specifically between the different regions of the Northern Hemisphere, but they everywhere show their common relation to a new and distinctly Carboniferous stock, so that in spite of varying generic names their consanguinity is unmistakable. Thus the *Aneimites* ("Cyclopteris" and "Adiantites"), *acadicus*, so characteristic of the Horton, is congeneric with and specifically close to the *A. bellidula* and other forms of the genus in the more northern regions, as well as probably with the genus Triphyllopteris of the Virginian region of the Appalachian trough. Some of the widely variant forms of the Horton plants are difficult to distinguish from the *Triphyllopteris virginiana* in the Pocono of the last-named region, though the species in their *ensemble* are distinct. Descendants of this stock are found in Eremopteris and possibly in Rhacopteris.

The stems described by Dawson as *Lepidodendron corrugatum*, the other monopolist of the Horton flora, present an almost bewildering cortical variation, which is well illustrated in the report of the "Plants of the Lower Carboniferous and Millstone Grit Formations of Canada." This singular and well marked Lepidodendroid type belongs to the older, composite, stock of the Devonian known as *Archæosigillaria*, in which the alignment of the leaf bases in vertical and transverse rows sometimes, when the growth was slow, produced vertical ribs resembling the Rhytidolepis group of Sigillariæ, while in other cases, especially when the growth was more rapid and the leaf scars were longitudinally more remote, it caused a verticillate aspect of the scars. The *Archæosigillaria* type of scar, first noted in *Archæosigillaria* ("*Lepidodendron*") *gaspiana* and *A. primæva*, the latter from the Portage group in New York, survive in *Eskdalia* and in *Bothrodendron*. *Archæosigillaria corrugata* is perhaps indistinguishable in any of its phases from the equally omnipresent and likewise monopolistic Lycopod described by Meek from the Pocono formation of the eastern United States as *Lepidodendron scobiniforme*. The latter is similarly varied in its cortical features. The Horton tree has its close correspondents in several contemporaneous Arctic species, such as *Lepidodendron glincanum*.

The dominant Cycadofilic and Lepidodendroid types of the basal Carboniferous flora of North America were evidently in a state of great plasticity and variation, under the new environmental conditions (coal formation) in

this continent at the beginning of the Carboniferous period.

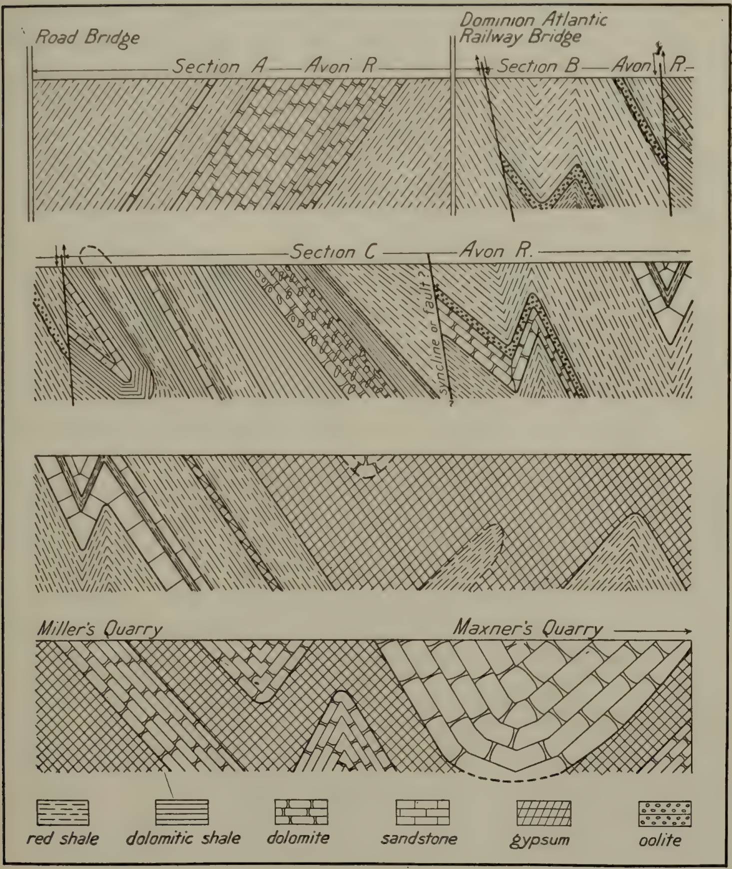
The Horton corresponds to the Pocono ("Vespertine"), which certainly is in part, at least, contemporaneous, in the central Appalachian trough, to the Cape Dyer beds, in the Cape Lisburne region of northwestern Alaska, to the coal-bearing basal Lower Carboniferous of Spitzbergen, Bear island, and Greenland, and probably to the lower portion of the Calciferous Sandstone series of Scotland.

THE WINDSOR SECTIONS.

GENERAL DESCRIPTION.

The sections about Windsor are so disturbed, disconnected and obscured with drift, that detailed field relations cannot as yet be given. The series comprises several hundred feet of soft brick-red and greenish-grey marls, interbedded with zones of gypsum and limestone, lying unconformably beneath deposits of Riversdale-Union age. Some of the limestone beds are of considerable thickness, while others occur as thin beds or zones between the shale or gypsum. The latter outcrops over a considerable portion of the area and has been extensively worked for many years. The type section of the Windsor limestones has been generally considered to be that exposed on the Avon river below the Windsor bridges. This section, however, has been given a prominence quite above its actual value in stratigraphy, as it is not only broken but also minutely deformed, so that the relations can only be appreciated by working in the mud at low tide. The accompanying section attempts to show the general relations of the rocks. The folding and faulting is locally very marked and the incompetent, yielding shales exhibit numerous pitching folds of small amplitude, frequently broken by small thrusts and with axial trends commonly parallel to the strike of the beds, while the thinner beds of sandstone or dolomite seem often to have yielded by brecciation in the closely mashed shales.

The Avon river marls and dolomitic limestones are separated by a thick zone of gypsum from the overlying Miller's Quarry dolomite beds. The latter at their full development are about 35 feet (7·6 m.) in thickness, lying between two zones of gypsum. Their contact with



Section from Windsor Bridges to Maxner's Point.

the overlying gypsum is obscured at the bridges but is well seen on the farther shore of the Avon, where 9 feet (2·7 m.) of transitional beds of gypsiferous shaly limestone carrying an extremely dwarfed fauna intervenes. The Miller's Quarry limestone is abundantly fossiliferous with Productids especially prominent. The gypsum above is again flexed in a shallow syncline at Maxner's point, preserving in its trough the Maxner's point dolomitic limestone. The upper beds of the limestone are likewise abundantly rich in fossils, especially in individuals of *Beecheria davidsoni*, *Dielasma sacculus*, *Pugnax sp.*, *Parallelidon dawsoni*, *P. hardingi*, and *Nautilus avonensis*. Following is a list of the more important species occurring in these Windsor sections:—

Vermes.
- *Cornulites*? *annulatus* Beede. (*Serpulites annulatus* Dawson.)

Bryozoa.
- *Rhombopora exilis* Beede, (*Stenopora exilis* Dawson.)
- *Fenestella lyelli* Dawson.

Brachiopoda.
- *Beecheria davidsoni* Beede, (*Athyris subtilita* Davidson.)
- *Dielasma sacculus* Beede, (*Terebratula sacculus* Davidson.)
- *Martinia glabra* Beede, (*Spirifera glabra* Davidson).
- *Spirifer cristatus* Davidson.
- *Camarophoria*? *globulina*? Davidson.
- *Rhynchonella pugnus*? Davidson.
- *R. ida* Hartt.
- *Productus semireticulatus* Davidson.
- *P. dawsoni* Beede, (*P. cora* Davidson).
- *Centronella anna* Hartt.
- *Pugnax sp.*

Pelecypoda.
- *Aviculopecten acadicus* Hartt.
- *A. debertianus* Dawson.
- *A. lyelli* Dawson.
- *A. simplex* Dawson.
- *Edmondia harttii* Dawson

E. anomala Dawson.
Cardinia subquadrata Dawson.
Liopteria dawsoni Beede, (*Bakewellia antiqua* Dawson).
Modiola pooli Dawson.
Parallelidon dawsoni Beede.
P. hardingi Beede, (*Macrodon hardingi* Dawson).

Gastropoda.
Naticopsis howi Hartt.
N. dispassa Dawson.
Platyschisma? dubium Dawson.
Loxonema acutulum Dawson.
Murchisonia gypsea Dawson.

Pteropoda.
Conularia planicostata Dawson.

Cephalopoda.
Nautilus avonensis Dawson.
Gyroceras harttii Dawson.
Orthoceras dolatum Dawson.
O. vindobonense Dawson.
O. laqueatum Hartt.
O. perstrictum Hartt.

Trilobita.
Phillipsia howi Billings.

Ostracoda.
Beyrichia jonesii Dawson.
Leperditia sp.

GEOLOGICAL AGE OF THE WINDSOR SERIES.

Previous to Lyell's visit in 1843, the Windsor series was generally regarded as lying above the Coal Measures, probably from the resemblance of the former to the gypsum-bearing Permian rocks of Europe. Even Logan [**9**] in 1842 was of the opinion that "the gypsiferous strata and the associated shales, sandstones, and fossiliferous limestones are not only newer than the coal-measures, but overlie them unconformably," founding his conclusions respecting the geological age of the formation on

its organic contents. The fossils, he states, "have a decided generic agreement with the fossils of the Triassic period". Gesner [**8**] also, in 1843 included the Windsor in his New Red Sandstone division. Murchison [**10**], in the same year, suggested a Permian correlation on the basis of the fossil determinations of de Verneuil, Keyserling and himself, but Lyell [**7**] shortly afterward overthrew previous opinions by his evidence in favour of the Lower Carboniferous age of the series, including in his "Travels" a short list of the characteristic species of fossils.

It remained for Dawson [**3**, pp. 278-314] in 1868, to present the most comprehensive description and illustration of the Windsor fauna, finding many of the species closely allied with species of the Mountain Limestone of England, while de Koninck confirmed his views and correlated the formation with the Carboniferous Limestone of Visé in Belgium. Davidson [**18**] had previously described many of the brachiopods submitted to him by Billings. How and especially Hartt have also contributed to our knowledge of this fauna.

Little work has since been done in adding to the faunal relations stated by Dawson. Schuchert [**19**], after several visits to the Windsor locality, stated in 1910 that "the oldest fauna of this series at Windsor includes but few species, and these remind one of Kinderhook time. In the higher dolomites at Windsor a rich fauna appears that is very different from that in any American Mississippic horizon, and as it is also unlike those of Europe it is difficult to correlate. Seemingly it is of Keokuk time, yet it may be somewhat younger as Lithostrotion is reported at Pictou, which is not far from Windsor." This view finds further corroboration in Beede's [**20**] description of the same fauna found by John M. Clarke in the Magdalen islands.

Industrial Notes.

Gypsum has been the only mineral of industrial importance mined in the Windsor district. The great quantities and accessibility of this rock to navigable waters gave an early impetus to its exploitation, and quarrying operations have been carried on in the vicinity of Windsor for over a hundred years. In Haliburton's "History of Nova Scotia", 1829, it is stated that nearly 100,000 tons were annually shipped to the United States, where it was

utilized as a fertilizer. In 1910, 322,974 tons were quarried in the province, of which 10,500 tons only were used in the home manufacture of gypsum products, the balance being shipped to the United States.

BIBLIOGRAPHY.

1. Daly, R. A.; Bull. Mus. Comp. Zool., Harvard College, Vol. V. No. 3, 1901.
2. Bailey, L.W.; Trans. Nova Scotian Inst. Sci., Vol. IX, 1894-8, pp. 356-360.
3. Dawson, J.W.; Acadian Geology, 2nd. ed., 1868, p.108.
4. Bailey, L.W , and Matthew, G. F., Geol. Surv. Canada, Rept. Prog., 1870-1, p. 218.
5. Bailey, L W.; Trans. Roy. Soc. Canada, Vol. III, 1897, pp. 107-116.
6 Kramm, H. E.; Geol. Surv. Canada, Summ. Rept., 1911, p. 326.
7. Brown, R.; Haliburton's Nova Scotia, 1829.
8. Gesner, A.; Proc. Geol. Soc. London, Vol. IV, 1843, pp. 186-190.
9. Logan, W. E.; Proc. Geol. Soc. London, Vol. III, 1842, pp. 707-712.
10. Murchison, R.; Proc. Geol. Soc. London, Vol. IV, 1843, pp. 124-125.
11 Lyell, C.; Travels in North America, 2nd. ed., Vol. II, 1855,
12. Fletcher, H.; Trans. Nova Scotian Inst. Sci., Vol. XIII, 1900, pp. 235-244.
13. Kidston, R.; Geol. Surv. Canada, Ann. Rept., Vol. XII, 1899, p. 203A.
14. White, D.; Can. Rec. Sci., Jan. 1901, pp. 271-275.
15. Woodward, A. S.; Geol. Surv. Canada, Ann. Rept., Vol. XII, 1899, p. 203A.
16. Lambe, L. M.; Geol. Surv. Canada, Sum. Rept, 1908, p. 177.
17. Lyell, C.; Proc. Geol. Soc. London, Vol. IV, 1843, pp. 184-186.
18. Davidson, T.; Journ. Geol. Soc. London, Vol. XIX 1863, p. 158.
19. Schuchert, C ; Bull. Geol. Soc. America, Vol. XX, 1910, p. 551.
20. Beede, J. W.; Bull. N. Y. State Mus., No. 149, 1910 pp. 156-186.

ANNOTATED GUIDE.

Windsor to Truro.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

Windsor. Alt. 26 ft. (7.9 m.). The Canadian Pacific railway from Windsor to Truro runs in an easterly direction through a district whose western portion is underlain by Carboniferous strata belonging to the Windsor series. The gypsum beds and associated limestones and shales of the Windsor series, outcrop over a large area bordering the St. Croix river on both sides. They extend to the south for a distance of about $2\frac{1}{2}$ miles (4 km.), and to the north for a distance of about 15 miles (24.1 km.) almost to the shores of the Bay of Minas. Over this wide area, the strata are folded, crumpled and doubtless, traversed by many faults. Though in many places the strata are vertical or steeply inclined, yet as a general rule, the angle of dip is not above 30°.

On the south, the Windsor series is bounded by the wide area of the Pre-Cambrian Gold-bearing series and the associated Devonian granites, traversed by the railway line from Halifax to Windsor. In places, narrow belts of Horton (lowermost Carboniferous) strata separate the Windsor beds from the older measures. The Windsor beds are unconformable to the Pre-Cambrian and possibly are also unconformable to the Horton. On the north, the Windsor beds are bounded by a narrow band, of irregular width, of sandstones, shales, slates, etc., which by Hugh Fletcher were considered to be Devonian and to unconformably underlie the Windsor strata. At least a portion of these so-called Devonian beds are the equivalents of the Horton series and therefore of Carboniferous age. Other portions may be the equivalents of the Riversdale-Union series and, if this be the case, are younger in age than the Windsor series.

Miles and Kilometres.

At a distance of 1 1-2 miles (2·4 km.) east of Windsor, the railway approaches the south bank of the St. Croix which flows westward to join the Avon at Windsor. From this point the railway for some distance closely follows the river and passes through several rock-cuts in gypsum. A short distance farther, the railway crosses to the north side of the St. Croix and follows up the valley of Hebert river, a small tributary of the St. Croix. The railway passes through a rock cutting in gypsum, and gypsum and limestone are exposed on the south bank of Hebert river.

6·3 m. 14·5 km. **Brooklyn Station.**—Alt. 33 ft. (10 m.). The railway follows Hebert river for 1 1-2 miles past Brooklyn and there turns to the north, crosses a low ridge (altitude 160 ft. or 49·8 m.) and descends to the valley of Kennetcook river. The country is gently rolling with relatively wide valleys.

12·1 m. 19·5 km. **Mosherville Station.**—Alt. 39 ft. (11·9 m.). The railway from Mosherville eastwards, ascends the wide, shallow valley of Kennetcook river which flows westward to join the Avon. The country is quite level and for a number of miles to the northward is boggy. As the river valley is followed eastward, it gradually narrows.

18·7 m. 30·1 km. **Clarksville Station.**—Alt. 70 ft. (21 m.). About 2 miles (3·2 km.) beyond Clarksville the railway crosses the Kennetcook (altitude 62 ft. or 18·9 m.). At this point the southern boundary of the area underlain by the Windsor series is about 2 miles (3·2 km.) south of the railway. To the south of the boundary lie so-called Devonian strata bordering a ridge of the Goldbearing series which terminates a few miles to the east. The "Devonian" strata encircle this ridge in anticlinal fashion and on the southern side of the ridge of the Pre-Cambrian Goldbearing series, are bordered by a wide area of the Windsor series. The ' Devonian" measures consist in part of sandstones and shales carrying, in places, thin coal seams. The "Devonian" strata appear

Miles and Kilometres.

to underlie the Windsor beds and for this reason were assigned to the Devonian by Hugh Fletcher. If, as the evidence seems to indicate, the "Devonian" beds so underlie the Windsor strata, it is still probable that they are of Carboniferous age and they may, in part at least be the equivalents of the Horton series.

16·5 m.
26·5 km.

Kennetcook Station.—Alt. 97 ft. (29·6 m.). At Kennetcook station the area of the Windsor series traversed by the railway narrows to a width of less than 1 mile (1·6 km.). The narrow band of the Windsor series is bounded on both sides by "Devonian" strata. On the northern side, the "Devonian" measures occupy a ridge about 11 miles (17·1 km.) long and 2 miles (3·2 km.) wide. The strata forming this ridge seem to lie in a shallow synclinal. They carry thin seams of coal and as pointed out by Fletcher, they resemble the Millstone Grit, though he mapped them as Devonian. Practically nothing is known concerning the palæontological evidence of the age of the so-called Devonian strata. As already stated, it is entirely likely that portions of the "Devonian" strata underlie the Windsor series, but it is equally probable that other portions are younger than the Windsor series and that they may be of Millstone Grit age, perhaps are in part equivalent to the Riversdale-Union group. The non-recognition of the presence of Pennsylvanian strata in the "Devonian" areas may have been due to the lack of any pronounced unconformity between the Millstone Grit and older Carboniferous, a condition that obtains in a number of the Carboniferous districts of Nova Scotia.

20 m.
32·2 km.

Patterson Station.—At Patterson and for several miles to the eastward, the railway passes through the "Devonian" area bounding, on the north, the narrow strip of Windsor strata.

Two miles (3·2 km.) to the east of Patterson station the railway again enters the band-like area of the Windsor series. About a mile farther the railway crosses the divide (altitude

Miles and Kilometres.

171 ft., 52·1 m.) between the headwaters of the westward flowing Kennetcook and of the easterly flowing Fivemile river. From this point, the railway descends the valley of Fivemile river to the Shubenacadie river.

35 m. 56·3 km. **Burton Station**—Alt. 141 ft. (42·9 m.). In the neighbourhood of Burton, the narrow area of Windsor strata that stretches along the upper part of the Kennetcook valley, joins a wider area which extends westward to the Avon at Windsor. This area extends eastward down Fivemile river valley but gradually narrows and near the mouth of Fivemile river leaves the river valley and dwindles away to a narrow strip only a few yards wide.

The valley of Fivemile river is very narrow. Exposures of gypsum, red shales and shaly limestone, and of red sandstone are visible at intervals.

One half mile above South Maitland, the river valley suddenly widens and the railway enters the area of "Devonian" strata that forms the south border of the Windsor area.

40·1 m. 64·5 km. **South Maitland Station**—Alt. 32 ft. (9·8 m.). A short distance beyond South Maitland the railway crosses Shubenacadie river. The dark strata of the "Devonian" are visible on the west bank of the river. The country on the eastern side of the river is underlain by strata of the Windsor series stretching for many miles in an easterly direction. After crossing the Shubenacadie, the railway for a short distance ascends the valley of a small brook, then bends to the north and climbs to the summit of a gently rolling country, (altitude of railway at summit, 235 ft. or 71·6 m.).

45·5 m. 73·2 km. **Princeport Station**—Alt. 212 ft. (64·6 m.). Beyond Princeport the railway crosses the northern boundary of the district occupied by the Windsor series and enters an area underlain by "Devonian" strata belonging to the Union formation.

Miles and Kilometres.

As the railway descends to the Triassic area bordering the Bay of Minas, this bay becomes visible and the gradually rising land on the opposite shore is seen.

50·8 m. 80·6 km. **Clifton Station**—Alt. 31 ft. (9·4 m.). Clifton station is close to the edge of the tidal flats bordering the estuary of Salmon river at the head of the Bay of Minas. Both sides of the river are bordered by Triassic strata. The Triassic strata are almost entirely red shales, sandstones and conglomerates and in this general district are nearly horizontal and quite undisturbed. The Triassic measures occur at intervals along the south shores of Minas Basin to the mouth of the Avon river and doubtless form the eastern prolongation of the Triassic area extending for above 100 miles (160 km.) eastward of the mouth of the Avon in the Cornwallis-Annapolis valley. The Triassic measures are not known to be fossiliferous but their correlation with the Newark series of the Atlantic states is well established.

57·8 m. 93 km. **Truro**—Alt. 60 ft. (18 m.). Truro is situated close to the southern border of the Triassic area, strata of the Union formation outcropping about ½ mile (0·8 km.) to the south of the railway station.

ANNOTATED GUIDE.

HALIFAX TO ENFIELD.

(G. A. Young.)

0 m. 0 km. **Halifax**—For description of route from Halifax to Windsor Junction, reference should be made to the itinerary of the journey from Halifax to Avonport, p. 133-4.

13·9 m. 22·4 km. **Windsor Junction**—Alt. 129 ft. (39·3 m.). Leaving Windsor Junction, the Intercolonial railway passes close to the western shore of a small lake. At the head of this lake, the railway enters an area underlain by dark slates of the upper division of the Goldbearing series. The

Miles and Kilometres.

slates form a belt about 3 miles (4·9 km.) wide in which the strata strike S.W.-N.E. and are folded along two synclinal axes.

Shortly after entering the slate belt, the railway approaches the head of Long lake and from this point follows northward along the western shore of the lake. The eastern shore of the lake, towards the foot of the lake, forms the western boundary of a granite stock having a diameter of about $1\frac{3}{4}$ miles (2·8 km.). The granite intrusion does not seem to have affected the structure of the surrounding beds of sedimentary rocks.

After passing the foot of Long lake, the railway turns easterly and runs parallel with the strike of the strata. The railway passes within sight of the head of Shubenacadie lake and crosses a small stream flowing into the lake. This small stream discharges the waters of a series of four long narrow lakes extending in a southeasterly direction up a narrow valley bounded by low hills rising to heights of between 150 feet (45 m.) and 350 feet (100 m.) above the sea. The most southerly of these four lakes is only 92 feet (28 m.) above the sea and distant only 3 miles (4·8 km.) from the Atlantic, being separated by a divide with an altitude of about 95 feet (28·9 m.) from a lake draining into Halifax harbour.

21·3 m. **Wellington Station**—Alt. 76 ft. (23·2 m.).
34·3 km. Beyond Wellington station the railway passes through several rock cuttings in dark slates, and as it approaches the eastern shore of Shubenacadie lake, enters a wide band of strata of the lower, quartzite division of the Goldbearing division. The strata in this belt are folded into two main anticlinal and a number of subordinate folds.

23·1 m. **Grand Lake Station**—Alt. 58 ft. (17·7 m.).
37·2 km. From this station is visible the high ridge (altitude 600 to 750 feet or 180 to 215 m.) bounding the Shubenacadie valley on the west. For some distance past Grand Lake station, the railway follows the shore of Shubenacadie

Miles and Kilometres.

lake and passes through rock cuttings in the quartzite series. Beyond this the railway passes along the western shores of a small lake and at Sandy Cove again approaches the shore of Shubenacadie lake.

25 m. 40·2 km. **Sandy Cove Station**—Alt. 62 ft. (18·9 m.). A short distance beyond Sandy Cove, the railway swings away from Shubenacadie lake and enters the Carboniferous area of the valley of Shubenacadie river which flows from the lake of the same name. The Carboniferous strata consist of beds of gypsum, limestone, shale, etc., and presumably belong to the Windsor series (Mississippian). The boundary between the Carboniferous strata and the Goldbearing series runs in a general easterly direction and for some distance is rather closely followed by Shubenacadie river. The railway crosses this stream a short distance from Enfield.

27·7 m. 44·5 km. **Enfield station**—Alt. 63 ft. (19·2 m.).

THE GOLDBEARING SERIES OF NOVA SCOTIA.

(E. R. Faribault.)

INTRODUCTION.

The Goldbearing series of Nova Scotia occupies the whole southern part of the peninsula of the province, extending along the Atlantic coast from Canso to Yarmouth. The series consists of a great thickness of conformable quartzites and slates closely folded in long east and west anticlines and intruded by many large batholiths of granite and some dykes of diabase. In the neighbourhood of the granite the sediments are metamorphosed into gneiss and schists. The age of the series cannot be determined by palaeontology as it is practically barren of fossils. From lithological analogy the strata have been regarded until recently as Lower Cambrian, but they are now believed to be late Pre-Cambrian in age. The gold deposits are in the form of quartz veins, chiefly interbedded, which are found aggregated in large numbers on the domes of

Anticline in the Halifax slate formation, showing the bedding and cleavage planes, interbedded and cross veins, and the arch-core of the fold plunging 5°, at eastern end of dome. The Ovens gold district, N.S., 1909.

pitching anticlines. Gold was discovered about fifty years ago and since that time the district has received the attention of many geologists.

The series is remarkable perhaps not so much for the amount of precious metal produced as for the enormous thickness of conformable sediments exposed, for the interesting variety of schists produced by igneous and dynamic agencies, and more specially for the beautiful dome-structure of the interbedded veins, the origin of which has provoked the constructive imagination of geologists for the last fifty years.

The geological structure of the greater part of the area of the series, from the eastern extremity to Liverpool and Kentville, has been surveyed in considerable detail for many years by E. R. Faribault [**10**], and the results have been published by the Geological Survey on map-sheets on the scale of one mile to an inch, on detailed plans of mining districts, and in many partial reports contained in the annual Summary reports. The southwestern portion of the region was mapped and reported on with less detail for the Geological Survey by L. W. Bailey. In the report compiled by W. Malcolm [**11**] and published in 1913 by the Geological Survey, entitled "Gold Fields of Nova Scotia", is presented a comprehensive and complete record of the results of the investigations made in the field. The present review of the subject is largely an abstract of that report.

The whole surface of the area of the Goldbearing series has been subjected to extensive erosion and all that remains of what was probably once a highly elevated mountain system, is a plateau reduced nearly to sea-level, showing the upturned edges of the closely folded beds and the low granitic masses that intruded them. The plateau has a general southerly slope towards the Atlantic, and its northern limit forms a long escarpment whose elevation varies in altitude from 500 to 800 feet (152 to 243 m.).

THE GOLDBEARING SERIES.

The Goldbearing series is one of the oldest series of sedimentary rocks in the province. It extends along the Atlantic coast the whole length of the peninsula, but is not represented in Cape Breton Island. The extreme length of the series from Canso to Yarmouth is 275 miles (442 km.) and the width varies from 10 miles (16 km.) at the eastern

end, to 75 miles (120 km.) at the western. Its area is estimated to be 10,250 square miles (26,568 sq. km.) or about half that of the entire province. Of this area, 4,000 square miles (10,368 sq. km.), or about one third, is occupied by intrusive granite.

This series was given the name of Meguma series in 1904 by J. E. Woodman [**6**]. It has however, been known so long and described so often under the name of Gold-bearing series that it is thought better to retain that name.

The sedimentary rocks consist essentially of a great series of quartzites and slates apparently conformable throughout, with practically no limestone nor conglomerate. The series has been divided lithologically into two distinct, conformable formations, the lower known as the quartzite or Goldenville formation, and the upper known as the slate or Halifax formation. In King's county, south of the Cornwallis Valley, the slates of the Halifax formation are overlain, apparently conformably, by a few thick beds of pinkish-white, massive quartzite and a series of dark and fawn-coloured slates which are nowhere else represented along the Atlantic, and to which is now given the name of Gaspereau formation. But, until the confority of these two formations has been proved conclusively, the Gaspereau formation can only be considered as a probable part of the Goldbearing series.

The total known thickness of the Goldbearing series, exclusive of the Gaspereau formation, is estimated to be 35,460 feet (10,808 m.), or nearly seven miles and including the probably conformable Gaspereau formation, 38,260 feet (11,662 m.) or nearly $7\frac{1}{2}$ miles.

Goldenville Formation.

The Goldenville formation consists mostly of thick-bedded compact, greenish and bluish grey quartzose sandstone, or quartzite, generally feldspathic and micaceous, often holding large cubes of iron pyrite and weathering light rusty grey. Interstratified with the quartzites are numerous beds of argillaceous, siliceous and micaceous slates of various shades of grey, sometimes arenaceous and passing into quartzites, and occasionally calcareous or pyritous. Towards the base, the slate beds become more numerous and often attain a considerable thickness. In the western end of the field at certain horizons, the slate

beds diminish in thickness and number and become very rare, while the quartzites increase in thickness and become massive, coarse and more siliceous. The thickness of the Goldenville formation, estimated to be 16,000 feet (4,877 m.) at Moose River, Halifax county, was found by Faribault in 1912, to exceed 23,700 feet (7,242 m.) on Liverpool bay, Queens county.

Halifax Formation.

The Halifax formation is composed essentially of argillaceous and siliceous slates of different colours, but mostly dark grey and black, graphitic and pyritous, passing at certain horizons into greenish and bluish grey talcose argillites, or into ribboned grey and light grey, chloritic, arenaceous beds. The black slates have numerous layers of flinty flags heavily charged with small cubes of pyrite which also occurs in massive form between the beds. The base of the formation is characterized, in some places to the eastward of Halifax, by a few beds of siliceous limestone. At the eastern end of the field the line of demarkation between the Goldenville and this formation is well defined by a sudden change from quartzite to slate, but at the western end the transition is more gradual and beds of quartzite are found interstratified with the beds of grey arenaceous slates of the overlying formation.

The thickness of the Halifax formation, as measured on the Black river to the base of the Whiterock quartzites of the Gasperau formation, is 11,700 feet (3,566 m.).

Metamorphic Phases.

Crystalline schists and gneisses of various kinds are found rather widely distributed throughout the field, but are of limited area. They usually occur in more or less continuous zones surrounding the granite masses, but they are also found in zones or irregular patches several miles distant from any outcrops of granite.

The gneisses consist chiefly of quartz and mica and are foliated and coarsely crystalline. The schists are mostly composed of mica often accompanied by crystals of staurolite, or andalusite, less commonly, by hornblende or garnet. Some layers are highly charged with pyrite

and in a few cases sillimanite was observed. The predominance of mica gives the rock a light silvery grey, shining lustre. The coarse, crystalline varieties of andalusite and staurolite schists are found mostly at the eastern end of the field, while the coarse hornblende schists are confined to the western end where they sometimes attain a great development.

In the metamorphosed zones surrounding the granite, every gradation from unaltered slates and quartzites to completely recrystallized schists and gneisses are noticeable as the granite is approached.

A slight amount of metamorphism, due to dynamic action, is also developed locally along the axes of some of the sharp folds where the rocks have suffered great compression, and this is specially noticeable in the eastern end of the field where the strata are more closely folded.

Structural Relations.

The importance of a knowledge of the structure of the Goldbearing series will be generally conceded when it is understood how intimately bound up with the geological structure is the distribution of the ore deposits. The unravelling of the structure is by no means easy. Only one horizon, the boundary between the Goldenville and Halifax formations, can be traced throughout the field, but, while in the east this boundary is sharp and distinct, in the west it is not nearly so distinct. The structure of the Goldenville formation is generally more easily deciphered than that of the Halifax in which the cleavage of the slates is often so much developed as to obliterate nearly all traces of stratification. Traverses made across the series from north to south show a succession of alternating zones of the Halifax and of the Goldenville formations varying in width from a fraction of a mile to several miles. A close study of the structure of these zones shows that the strata are closely folded in a series of long parallel anticlines and synclines, the tops of which have been extensively eroded.

In the eastern part of the field the width of the quartzite zones is generally much greater than that of the slate, while in the western part, the two formations are more nearly equal in width. In the eastern half these zones extend in a general east and west direction, while in the

western half they take a northeast and southwest direction. The slate zones of the east take in general the form of much elongated ellipses surrounded by quartzite, while in the west the zones of quartzite are mostly elliptical in shape, and they are surrounded by slate. The chief difference between the structure of the east and that of the west is that, in the east the folds are much more tightly compressed, the strata in the east commonly dipping at angles varying from 60° to 90°, while those in the west generally dip at lower angles. This is probably due to the predominance of the thick, massive and inflexible beds of quartzite in the west offering more resistance to the pressure than the alternating thinner beds of quartzites and slate beds of the east.

Along the anticlinal axes the strata lie in a series of dome-shaped folds or "domes", the axes of folding pitching alternately to the east and west. It has been thought that these domes were produced by a second series of parallel folds crossing the east and west series at a high angle. There is, however, no such alignment of the domes in the east, though in the west it does occur in some places where broad folds or undulations are found here and there having a northeast and southwest orientation, but generally only for short distances. In Queens county there is an important transverse anticlinal fold, producing a general doming of the main anticlines and an extensive development of the quartzite. The result is that the lowest known beds of the series are exposed at the surface. The compression that produced the pitching folds was probably contemporaneous with that producing the long east and west folds and generally was local in its action.

Whereas the anticlines are approximately parallel they vary in length from a few miles to 100 miles (160 km.). In some places two anticlines unite to continue as one, several subordinate crumples being formed at the place of union. In other places one anticline dies out only to be succeeded a short distance north or south by another, or it may be broken up into a series of short folds arranged en echelon the whole combining to make one great fold. Subordinate small crumples a few miles in length, on the limbs of the main anticlines are exceedingly common, particularly in the west, and more specially in the Halifax formation. In this formation the slates, on account of their more plastic nature crumpled into small folds more

readily than the quartzites. The pitching anticline of a dome of quartzite surrounded by slate also in many places divides into several crumples where it comes to the slate.

The main folds are on an average about 3 miles (4.8 km.) apart, and the domes along the different anticlines are from 10 to 20 miles (16 to 32 km.) apart. While the limbs of the anticlines dip generally at high angles and are frequently overturned, the pitch to the east or west is seldom more than 30°. At Oldham the south limb dips 70° and the north one 60°, while the pitch is west 25° and east 40°. The pitch varies greatly within short distances. At Waverley the pitch increases from 5° to 24° within 500 feet (150 m.); at Oldham it increases from 30° at the surface to 40° at a vertical depth of 900 feet (270 m.).

The Goldbearing series has suffered a great deal of faulting and the fractures may be grouped into two classes, namely, cross-country faults and local faults.

The local faults are those that are found in the separate gold districts only and do not continue for great distance along the strike nor in depth. They are closely related in origin with the doming of the anticline and are frequently found to radiate from the centre of the dome, as in the eastern part of Oldham.

The cross-country faults are those that can be traced several miles across successive folds. They form a series of breaks approximately parallel and have a northwest and southeast direction. Nearly all those in the eastern half of the field are known as left-hand faults, that is the horizontal displacement is to the left of one facing the fault from either side. Those in Kings county, on the contrary, are right-hand faults. The faults in many cases have determined the remarkably straight courses of some of the river and brooks, and the alignment of swales and numerous cold water springs. The most important faults are found in the eastern end of the field. Some have been traced the whole width of the series and their horizontal displacement along the strike varies from a mile and a half to a fraction of a mile. The numerous faults of Kings county have a horizontal displacement varying from a few feet up to 900 feet (275 m.).

In addition to the folding and faulting produced in the rocks, other phenomena such as brecciation, cleavage, jointing and fissuring have resulted from the forces to which they were subjected. It seems probable that the innumerable

quartz veins lying in the stratification planes on the domes had their origin in the deposition of quartz in fissures produced by the close folding and the consequent slight slipping of the strata upon one another. The fissures in which cross-veins were deposited, are also probably due to movements but, unlike those in which the interbedded veins were deposited, are quite local. A few cross-veins lie in fault planes of greater magnitude.

Cleavage is well developed throughout the field. In some places and more especially in the vicinity of sharply folded anticlines and synclines, the quartzite is squeezed into quartz-schist and the slate into mica-schist. The planes of cleavage are parallel with the axis of the folds, and are highly inclined, often only several degrees from the vertical. It is a noteworthy fact that in the vicinity of an anticline the planes of cleavage dip towards the centre of the fold. In those slate beds carrying quartz veins the cleavage plane is frequently found to curve aside on approaching the crest of a corrugation. Distinct serrations are frequently found along bedding planes and are due to motion along the cleavage plane, and it may be that some of the small crenulations found in the quartz veins are due to the same cause.

At the apex of the anticlines the thickness of the beds of slate of the Goldenville formation is often much greater than on the limbs. As folding proceeded there was some sliding of the beds upon one another, pressure at the apex of the folds was somewhat relieved, and the slate being more plastic than the quartzite was squeezed from the limbs to the apex. In some places the pressure was great enough to force all the slate aside and bring the beds of quartzite together. The compression of the beds on the limbs of the folds must have had the effect of diminishing considerably the original thickness of the sediments. In calculating the thickness of the series, this compression was not taken into account, so it is reasonable to suppose that the original thickness must have been much greater than that measured, but how much greater it is difficult to estimate.

Age.

The Goldbearing series has been referred by different writers at different times to various ages from Pre-Cambrian to Ordovician. Although a Lower Cambrian age has been

most generally applied to the series for a number of years the weight of evidence seems to point to an earlier origin, probably Pre-Cambrian. Certain markings or forms have been discovered from time to time and by some students have been thought to indicate an organic origin but these have in many cases turned out to be nothing more than concretions, or their organic origin has been disputed, and none have been characteristic enough to be of any determinating values. Of the contiguous formations, the oldest seems to be a series of fossiliferous rocks in Annapolis and Digby counties ascribed to the Silurian or early Devonian. In determining the age of the Goldbearing series therefore, lithological resemblances and analogies with distant formations have had to be resorted to, but, although suggestive, they can hardly be regarded as absolutely determinative.

Dawson [**2**] and Hind first considered the series as probably Ordovician. Later Selwyn pointed to their resemblance to the Lower Cambrian and Lingula flag series of North Wales, and still later, Dawson [**2**] believed the series to be Cambrian. Different authors have pointed out the resemblance existing between the Goldbearing series of Nova Scotia and the Pre-Cambrian slates and quartzites of the Avalon peninsula of Newfoundland. Murray as early as 1868 advanced the opinion that the resemblance "is too striking and marked to be overlooked, and the inference is that on further inquiry they will prove to be of the same age." Walcott, Van Hise, and Matthew also hold the same views.

In a study of that area lying south of Wolfville and Kentville, Kings county, Faribault (1908) has shown that, with the exception of the Silurian strata of New Canaan, all the rocks appear to be conformable and to belong to the Goldbearing series, and to include the fawn slates in which *Dictyonema websteri* was found at the same horizon at different points.

Thus the problem still remains to be solved; and, until more conclusive evidence is obtained the series may be regarded as most probably Pre-Cambrian.

GRANITE INTRUSIVES.

Granite is distributed widely throughout the series in the form of batholiths, the largest of which extends from the coast at Halifax westward in the form of a crescent, nearly

to the western end of the province, dividing the sedimentary series into two parts, an eastern and a western. In the eastern part of the field, some of the batholiths are also quite extensive in area, others assume the form of parallel bands a fraction of a mile wide and several miles long, cutting the sedimentary rocks at slight angles. At Liverpool bay, large granite dykes occur that also have a tendency to follow the stratification planes.

The composition and texture of the granite vary much with the locality and mode of occurrence. The rock consists for the most part of a light-grey or reddish-grey, coarse, porphyritic, biotite-granite, generally studded with large phenocrysts of white or pink-white feldspar. In the west, a light pearl-grey or pinkish-white, fine-grained, muscovite-granite occupies small areas penetrating the biotite-granite as well as the sediments. With the muscovite-granite are associated dykes of coarse pegmatite often passing to quartz, and bearing a large variety of minerals.

The granite is found everywhere to cut and penetrate the sediments; it cuts also the anticlinal and synclinal folds, and the interbedded quartz veins, without affecting in the least their original structure. In the vicinity of the granite the clastic rocks have been metamorphosed into gneisses and schists, the degree of metamorphism being greatest near the granite. The line of contact is sometimes sharply defined, but generally there is apparently a gradual transition from slate and quartzite to granite which in many cases is such as to suggest the assimilation of the intruded rocks by the large subjacent igneous masses. Within the granite areas are included large and small insular patches of altered sediments whose original structure is apparently not disturbed, and the granite itself often contains numerous small inclusions of sedimentary rock partially absorbed.

The granite intrusion took place during the Devonian period; it affected the Nictaux-Torbrook rocks which are placed at the base of the Devonian and it is on the other hand overlain unconformably by the Horton series which has been referred by some writers to late Devonian and by others to Lower Carboniferous.

BASIC INTRUSIVES.

Basic intrusions, taking the forms of dykes and sills, are found cutting the sediments, but they are confined almost wholly to the western part of the field. In Kings

county, on the northern margin of the series, these intrusions are numerous. They vary in thickness from a few inches to 100 feet (30 m.) or more, and nearly all lie in the bedding planes of highly inclined strata. A dyke of rusty weathering diabase, 100 to 900 feet (30 to 275 m.) thick, has been traced along the shore in Queens and Lunenburg counties for over 25 miles (40 km.). This intrusion has altered the sediments and impregnated them with magnetite for a few inches on each side.

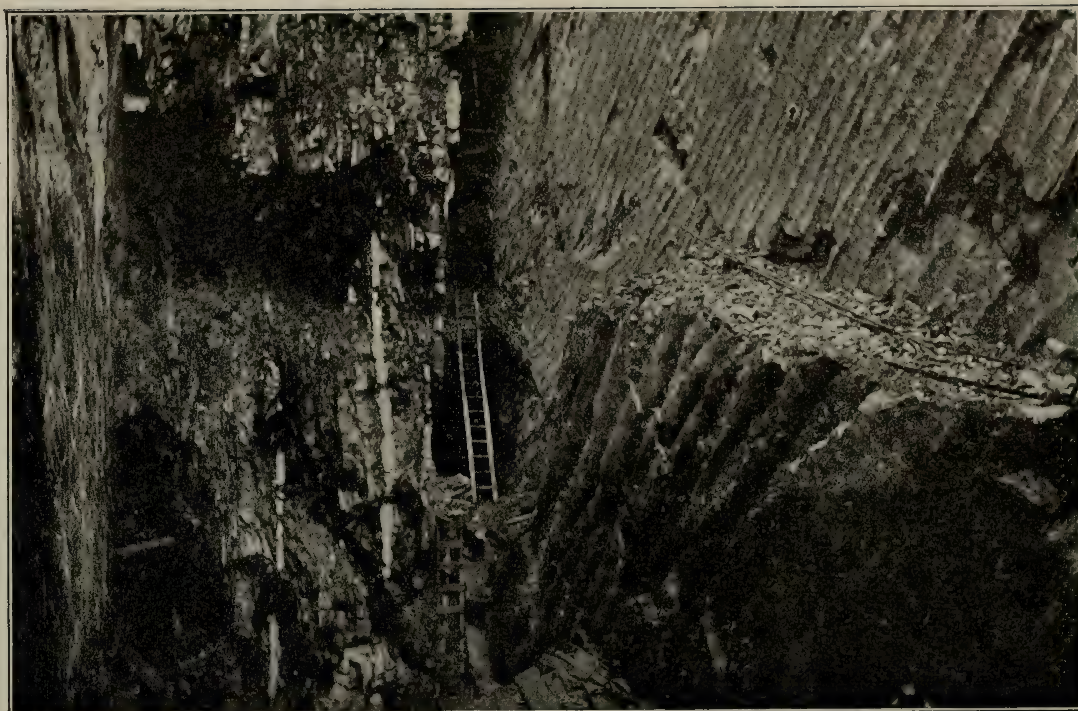
The basic rocks are generally dark greenish, diabase or diorite, and have undergone much alteration and in the case of the narrower bodies, have become quite schistose. Those of Kings county are probably roughly contemporaneous with the folding but older than the faults crossing the series, showing that they are of a great age. Like the granite they are probably Devonian but the relation of the two intrusive rocks has not yet been exactly determined.

THE GOLD DEPOSITS.

General Character and Distribution.

The gold deposits are the only deposits of the area that are of any considerable economic importance. These nearly all occur in quartz veins, but a small amount of gold has been recovered from detritus. The deposits of auriferous antimony ore occurring in cross-country veins in the Halifax formation at West Gore have been worked considerably for antimony and gold.

The gold-bearing quartz has been reported as occurring in the granite, but the authenticity of the reports may be regarded with suspicion. With this possible exception, all the known veins occur in the sedimentary strata of the Goldbearing series. Although there are a few important veins that cut across the stratification, most of the auriferous quartz veins are of the interbedded type. They occur chiefly in the beds of slate which are found interstratified with the beds of quartzite throughout the whole thickness of the Goldenville formation, and their distribution and structure are to a great extent the result of the action of dynamic forces to which the enclosing rocks were subjected. The interbedded veins are found in great numbers, aggregated in groups on the domes along



Corrugated hanging-wall of quartzite and section of quartzite and slate beds, with intercalated veins, on south side of the anticlinal dome. Mount Uniacke. N.S., 1909.

the anticlines; and in some few cases on the pitching portion of the anticlines. Rarely they are formed in the synclinal troughs. The domes thus determine the location of nearly all the groups of veins and each of them may be considered as an independent gold district. Some domes however, especially in the west, do not show the presence of quartz veins, but this appearance may be simply due to the concealment of the bedrock by drift.

A tabulation made of the principal anticlines with the gold districts located on them, from the map-sheets published by the Geological Survey, shows that to the east of Halifax 33 gold districts are distributed along 14 anticlines in an area 40 miles (65 km.) in width by 100 miles (160 km.) in length.

The gold-bearing districts are much less numerous and generally less productive in the western part of the field than in the east. This is chiefly due to the folding being more gentle and the domes broader, hence the slipping of the beds and fracturing has been less pronounced with the consequent failure to produce channels favourable for the circulation of solutions and the deposition of vein matter.

Quartz, with hardly an exception, forms by far the largest proportion of the vein filling, but occasionally inclusions of country rock or certain minerals are quite abundant. Associated with the quartz, the principal minerals are pyrite, arsenopyrite, calcite and galena, less frequently chalcopyrite, sphalerite, dolomite, chlorite and pyrrhotite, and more rarely scheelite, stibnite, feldspar, rutile and specular iron.

Silver is found in the gold recovered from cross-veins at Leipsigate, Brookfield, and some other districts, sometimes in such amounts as to reduce the value of the product to $16 an ounce. But the gold produced from the interbedded veins is generally very fine and varies in value from $19 to $20 per ounce. The gold generally occurs free and visible and is amenable to amalgamation, but it is also in part intimately bound up with the sulphides, thus requiring other methods of treatment for its recovery. In the white, coarsely crystalline quartz it is found in coarse, visible particles, while in the bluish, oily quartz of the laminated veins it is usually disseminated more finely or is found in plates in the layers parallel to the walls. It is generally most abundant on the footwall, is very

commonly associated with arsenopyrite, frequently in lenses or nodules forming large nuggets, and almost invariably with galena. Small crystals of gold are sometimes found in rhombic dodecahedra and octahedra, generally distorted, with bevelled edges and finely striated surfaces. Plates and scales are often found in the adjacent slate, but close examination always reveals the presence of minute films or threads of quartz traceable to the parent vein.

Interbedded Veins.

As has already been pointed out the auriferous veins are found on domes, although in some few cases, as at the Richardson mine, they are found on the pitching parts of anticlines remote from domes. In such cases, however, conditions favourable for ore deposition have been brought about by a notable change in the angle of pitch, producing virtually a doming of the anticline that is not apparent at the surface.

The distribution of the veins on any particular dome is intimately related to the rock structure, and complexity is introduced by the unsymmetrical character of the domes. On sharp, closely folded anticlines, where the two limbs form an angle of less than 40° or 50°, the veins are found close to the apex and curve over the anticline forming a succession of superimposed saddles, similar to the "saddle-reefs" of Victoria, Australia. On broad folds, on the other hand, where the angle formed by the two limbs is over 45°, the veins are found at a greater distance from the axis, but generally within the limit of curvature of the strata of the fold beyond which the dip ceases to increase and becomes uniform. If one end of a dome is flatter than the other, the veins at that end are further removed from the axis than at the other; and if veins occur on both limbs of a transversely unsymmetrical dome those on the limb with the higher angle of dip will be nearer the axis and more abundant than those on the limb with the lower dip. In many districts, the veins are found on one limb only and then they invariably occur on the limb with the higher dip, which is generally the south dip.

The interbedded veins have a more or less crescentic outcrop. On the sides of long domes, they form nearly straight lines, but finally curve with the strata around the

apex of the fold, and some have been traced continuously around the end of the dome from one limb to the other. But generally, the outcrops of veins form only small portions of elliptical curves, and these are most frequently arranged *en echelon* so that they lie in zones radiating from the centre of the dome and diverging more or less from the major axis according as the fold is broad or narrow. These zones are on those parts of the dome where the strata do not strike approximately parallel with the axis of the fold but curve towards the axial line. In symmetrical domes, like that of Oldham, there may thus be four zones, and these four zones may be considered as merging into one another so as to favour the formation of veins, the outcrops of which form almost complete ellipses. In most districts, however, there are only two zones of veins, as at Waverley where they may be regarded as merging into one to form saddles; and in some districts there is only one zone, as at South Uniacke.

In some districts the formation of veins seems to have been dependent on small subordinate folds or flexures. In some places there is a curving of the main axis of the fold and in such cases veins are found to be much more numerous and auriferous on the convex side of the axis. In some domes there is a torsion or twisting of the fold adding to the complexity of the structure and occurrence of the veins.

Mining operations in several districts have shown that underlying the veins exposed at the surface are other parallel interbedded veins. Each district has thus a vein-bearing zone with a horizontal extent determined by the outcropping veins and with an indefinite vertical extent. In its vertical extension each zone is believed to be roughly parallel with the axial plane of the anticline. The distance of the exposed veins from the axis depends on the dip of the strata, and it is probable that the distance from the axial plane of any portion of the zone of veins extending into the earth is also dependent on the dip; if the fold gets sharper with depth, the zone of quartz veins probably approaches the axial plane, or if it flattens with depth, the zone of auriferous veins recedes from the axial plane.

Most of the veins lie in slate beds varying in width from a fraction of a foot to a few feet. Rarely they lie in the middle of the bed and, as a rule, only when the bedding is marked by some difference in composition or texture,

producing planes along which fracturing took place. By far the greater number lie on the foot-wall with only a thin film of crushed slate or gouge separating them from the quartzite. Occasionally, the quartz is "frozen" to the wall.

As a rule the veins are quite conformable with the strata, but occasionally they pass from one wall to the other. A saddle-vein may have one leg on the footwall and the other one on the hangingwall. On a small crumple, the vein may lie on the footwall of that part above the crumple and on the hanging wall in that part below, forming irregularly shaped veinlets and quartz masses scattered all through the slate belt where it passes from one wall to the other in the short limb of the crumple. Some veins bifurcate, and one portion passes to the hanging wall, while the other remains on the footwall.

Some slate beds are found to carry several quartz veins, generally conformable with the strata, and constitute those large bodies of low grade ore, often 5 to 20 feet (1·5 to 6 m.) thick, that have of late years been worked with profit. These deposits are designated "belts", while the well-defined vein is designated a "lode" or "lead". The belt is sometimes also composed of a network of veins, the veinlets following the bedding planes for short distances and then crossing obliquely to join other veinlets.

Corrugated Veins.

Interstratified veins often exhibit a remarkable folded or corrugated structure within the beds of slate that contain them. The corrugations, or crenulations, usually occur at or near the apex of the anticline and sometimes in the syncline, and run parallel with one another and in a direction approximately parallel with the axis of the fold. At the apex of the fold, the corrugations dip with the dip of the strata, which then corresponds to the pitch of the fold, but on each side of the apex they radiate more or less from the centre. The amplitude and interval of the folds generally vary with the thickness of the vein and of the enclosing bed of slate. Also the nearer the veins lie to the anticlinal axis, the more pronounced these corrugations become. In some veins the folding has been so intense as to separate the quartz with disconnected rolled portions. The name "barrel" quartz has been given to the larger corrugations,

Serpent vein crumples between beds of quartzite above and slate below on the western plunge of anticlinal dome. Tourquoy mine, Moose River, N.S.

because when such a corrugated deposit was first uncovered at Waverley, it looked to the miner like the back or top of barrels lying in rows.

The slates beds adjacent to the corrugated veins show a sympathetic folding which extends for a few inches to a foot or two from the vein and gradually dies out. Seldom is the influence felt in the quartzite beds ,and then only in connection with the larger corrugations on the apex of an anticline.

Where one of the corrugations becomes enlarged or some part of a vein swells out and takes on some peculiar form extending for some distance in one direction, this portion of the veins is called a "roll". A roll is generally richer than other parts of the vein. Its position is usually dependent on some peculiarity of rock structure such as some small subordinate crumple, some slight flexure in the beds indicating an incipient crumpling or some zone of fracturing. As such structures usually affect a great thickness of strata, a number of veins is affected by similar conditions and a roll in one vein is succeeded by similar rolls in the underlying or overlying veins. Series of such rolls are found in most districts and constitute one of the principal and more persistent forms of ore deposits.

Thickness of Interbedded Veins.

The thickness of the interbedded veins varies from a fraction of an inch to 20 feet (6 m.). The greater number may not be over an inch, (25 cm.) but those that have been worked, generally vary from 3 to 18 inches, (7 to 45 cm.). The largest veins are usually found on sharp anticlines in the shape of saddle veins. Saddle veins attain their maximum thickness at the apex of the fold and become thinner as they extend down on the limbs. Thus the Richardson saddle vein while 20 feet (6 m.), thick at the apex thinned down to 6 feet (1.8 m.) at the 300-foot level. Some leads have been followed in depth several hundred feet with little or no decrease in size, but others have been found to pinch to a mere film and it is probable that nearly all of them pinch out at no great depth. The Dominion lead at Waverley was found to decrease from 15 inches (40 cm.) on the surface to a mere film of quartz with small lenticular pockets at 500 feet (150 m.) and to be completely wanting at 600 feet (180 m.)..

Veins are frequently thickened by local disturbances, such as a bend, a crumple or a faulting of the strata.

Although leads show a great similarity and are very numerous, yet many of them possess a certain individuality, some peculiarity of colour, structure, lamination, distribution of sulphides, quantity or form of gold, serving to distinguish them from others of the same district.

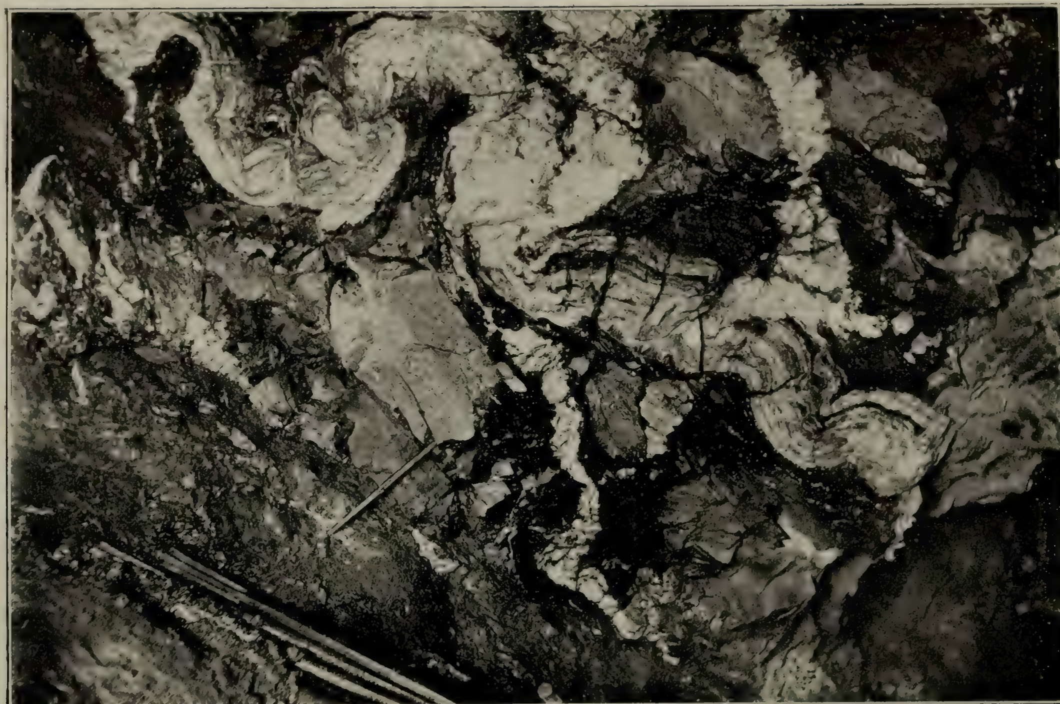
Cross or Fissure Veins.

A few important veins cut across the strata for a considerable distance, and in some districts they form the principal auriferous deposits. These cross veins, often spoken of as fissures, sometimes curve and branch, contain inclusions of country rock, and have a gouge on the walls. All the most important are found on domes, generally cutting the main anticline at various angles. They occur chiefly in the Goldenville formation, but also in the Halifax formation, especially at the base. Seldom does a cross vein lie in the fault plane. In the case of the Cope lode of Central Rawdon and the Baker vein of Oldham, which are exceptions to this rule, the faults are probably younger than the veins.

The thickness of the cross veins is less regular than that of the interbedded veins, probably because they generally intersect alternating beds of different hardness. They do not attain great thickness, except sometimes at their intersection with interstratified leads, flexures or rolls. The mineral content is generally the same as that of the interbedded veins, but the laminated structure is wanting. In many cases the value of the gold extracted is much reduced by the presence of silver. At West Gore enough stibnite was found to form gold-antimony ore deposits of considerable value and extent.

Bull Veins.

There is another kind of vein differing much from those already described. It may cross the strata or roughly lie in a stratification plane. It shows little or no trace of lamination, carries few metallic minerals and is composed of white crystalline quartz in which geodes with quartz crystals are sometimes found. These veins are usually thicker than the others, varying from one to several feet. They are not auriferous and are known as bull veins.



North leg of the Richardson saddle-vein at a depth of 400 feet, showing banded and corrugated structure, with angulars entering from below and leaving above. Richardson mine, Isaac's Harbour, N.S., 1905.

Angulars.

Many of the main veins have branches passing into the foot or hanging wall. These branches are termed angulars, and they play an important part in the ore deposition in certain veins. The point from which an angular passes from the main vein into the hanging wall is usually higher than that from which it passes into the footwall, and the intervening portion of the vein is frequently thicker and richer than other portions. Their distribution and attitude is dependent on the structure of the dome. In some parts of a dome they may be numerous or completely absent; they may have a general strike and dip quite different from what is found in another part of the dome. In crossing the bedding, they generally run nearly perpendicularly to the quartzite but obliquely through the slate. In a closely folded anticline they are more numerous at or near the apex, where they often form a reticulated system of veins extending along the axial plane from one lode to an overlying or underlying one.

The quartz of the angulars differ from that of the main veins in being of a fine, granular texture, free from laminations.

ORE DISTRIBUTION.

All the veins are not auriferous. The coarsely crystalline quartz seldom carries gold, while the laminated veins of oily quartz-bearing sulphides, generally do. In a few auriferous veins the gold seems to have had a fairly uniform distribution, but experience has shown that in most of them there was more or less segregation into pockets and shoots.

Some of the richest ore mined has been found in pockets. In the Blackie lead at Oldham the gold was found aggregated chiefly in nodules of arsenopyrite; and in the Hay lead lying 1,800 feet (548 m.) north of the anticline of the same district, an isolated pocket carrying 60 ounces of gold was found at the intersection of an angular with the main lead.

The great proportion of the ore, however, lies in shoots having more or less definite boundaries and directions. They vary from 20 to 60 feet (6 to 18 m.) or more in breadth and are frequently accompanied by a thickening of the vein. In interstratified veins, many shoots have

Lake lode ore-shoot in Halifax slate formation at a vertical depth of 1000 feet.
Caribou, N.S., 1904.

been worked to a vertical depth of 300 and 400 feet (90 to 120 m.). A shoot on the Hard lead, South Uniacke, was followed 1,200 feet (360 m.) on a dip of 28° east; while that in the Sterling Barrel lead, Oldham, has been worked to a depth of 1,610 feet (487 m.) on a dip varying from 30° at the surface to 43° at a vertical depth of 900 feet (275 m.), and in 1909, the ore averaged 2·88 ounces per ton. The latter is the deepest mine on an interbedded vein.

Several shoots in cross veins have also been mined to a vertical depth of 200 and 400 feet (60 and 120 m.), and two, to a vertical depth of 1,000 feet (300 m.); one of these was worked throughout a length of 2,000 feet (610 m.).

As a rule, ore-shoots occur in the rolls that have been already described, that is those parts of the veins in which there is some irregularity in size, form, structure or composition.

The interbedded leads are frequently found to be very rich at their intersection with angulars as well as in the thickened parts lying between the lines of intersection with angulars from below and above. All angulars do not enrich the leads they cut, and frequently only a set coming from some one particular direction have favoured the enrichment of the leads. The angulars themselves are usually not auriferous, but some have proved gold-bearing, especially in those parts where they cut obliquely across slate beds.

There is much irregularity in the distribution of the ore in belts; in some, all the veins are auriferous, in some, only one, and in others, one vein will be auriferous for some depth, then becomes barren and an adjacent one becomes auriferous.

That there is some order in the distribution of the ore-shoots was pointed out by Poole as early as 1878. A study of the plans made by Faribault of the different gold districts, reveals an alignment or arrangement of the outcroppings of the ore-shoots in nearly every district. In the case of sharply folded anticlines, the line of ore-shoots runs roughly parallel with the axis or diverges slightly from it, radiating from the centre of the dome, while in broad folds the line diverges still more from the axis. The shoots pitch in the general direction of the pitch of the anticline and at about the same or a little higher angle.

In some veins two or more parallel shoots have been found. The ore-shoot on the Hard lead, South Uniacke, really consists of two streaks lying 40 feet (12 m.) apart; in the Mulgrave lead, Isaacs Harbour, a shoot 30 feet (9·1 m.) broad lay 180 feet (54·7 m.) below another 12 feet (3·6 m.) broad, both pitching west at an angle of 12°.

The distribution of the shoots is frequently dependent on some subordinate flexure or crumple in the strata. For example, the large series of ore bodies worked at Renfrew is due to a subordinate undulation in the strata on the south limb of the dome. In this regard each district has its individuality, the structure of one dome never being just the same as that of another. The distribution of the ore-shoots, consequently, is never exactly the same in any two districts.

In cross veins the ore body is found, in some cases at least, to lie at the intersection of the vein with certain strata or main leads. At Cow Bay, the ore body dips south at the same angle as the strata and follows certain beds at the base of the Halifax formation highly charged with pyrrhotite. The shoot, followed 2,000 feet (610 m.) in the Libbey vein, extended from its intersection with the Mill lead on the north to the vicinity of its intersection with the Jim lead on the south.

PAY ZONE.

Certain facts point to the existence in most districts of zones extending to a considerable depth in which a succession of auriferous, interbedded, quartz veins of similar character and extent lie superimposed one above the other. On the north limb of the anticline at Goldenville several parallel veins lying close together pass under one another, and each has been worked to some depth beneath the overlying veins. An example of superimposed saddle-shape ore bodies on the apex of the anticline is found at Isaac Harbour where the workings of the Burke lead was carried below those of the Archie, McPherson and Saddle leads. So also at Mount Uniacke, a series of ore-shoots was worked on the West Lake, Nuggety, Little and Borden leads where they are affected at successively greater depths by a subordinate crumple with an axial plane dipping north at a high angle.

The observation of these and numerous other relations led the writer to the propounding of the "pay-zone" theory* As has been pointed out the distribution of ore-shoots is dependent on the structure of the anticlinal fold or subordinate flexures on the fold: they lie in a line passing through similarly curved or twisted portions of the strata that during the folding process were subjected to pressures and tensions and were fractured so as to permit the transmission and deposition of minerals. The subordinate flexures and peculiarities of structure, on which the distribution of ore-shoots depends, extend to an unknown depth, and it is claimed that interbedded veins and ore-shoots should succeed one another with depth so long as the same structural conditions continue as at the surface. These structural conditions generally extend in depth parallel to the axial plane of the dome. We thus get a pay-zone the surface extent of which coincides with the surface over which the ore-shoots outcrop and which extends parallel with the axial plane of the dome to an indefinite depth.

The evidences in favour of the theory are the fact that gold mining has been carried on in the province to a vertical depth of 1,000 feet (300 m.) in fissure veins and 900 feet (275 m.) in one interbedded vein; that pay-ore is not limited to any particular horizon, but has been mined throughout the whole thickness of the Goldenville formation; and the analogy existing between the interbedded veins of Nova Scotia and the saddle-reefs of Bendigo, which have been worked successfully to a depth of over 3,000 feet (900 m.) and proved auriferous at over 5,000 feet (1,525 m.).

While the hypothesis may be of general application it is not claimed that it will hold in all particular cases. Structural features vary with depth; subordinate folds may not persist and main folds may flatten and thus the pay-zone may die out or be shifted in position with regard to the anticlinal axis. For example, in the case of the Dufferin mine, rich ore was found at the apex of the fold at the surface, but in the underlying veins owing to the flattering of the dome it was more remote from it.

*Geol. Surv. Can., Vol. V. p. 57 A. A. and Vol. X. p. 108 A.

Genesis.

Some of the earlier investigators such as Hind and Hunt, maintained that the interstratified veins are syngenetic, that is, were formed contemporaneously with the containing rocks, but later students of the Nova Scotia gold fields are thoroughly convinced that they are epigenetic, i.e., deposited subsequently. That the cross-veins are of later origin all are agreed.

Campbell, the pioneer in the gold fields of the province, expressed the opinion that the veins were of later origin than the rocks, and Selwyn and Poole were strong supporters of his theory. The opinion that prevails to-day is that the veins were formed during the folding of the rocks, in the openings produced by the movements of the strata. During the folding of the interstratified beds of slate and quartzite, or shale and sandstone, there was a certain amount of slipping of one bed over another. This slipping produced openings along the bedding planes, which were in general widest at the apex of the folds, and decreased in width with depth along the limb until at a depth of a few hundred feet they pinched out. During or subsequently to the formation of these openings, which took place within the less resistent beds, the vein filling was introduced by solutions. Thus is explained the dependance of vein distribution on rock structure.

The arching of the rocks on closely folded symmetrical domes produced fissures passing over the apex and down each limb; on broad domes the arches were not strong enough to sustain themselves and the fissures were formed only on the limbs; on unsymmetrical domes the slipping of the strata was such as to produce fissuring along the bedding planes of the limb with the higher angle of dip; and subordinate flexures, in which the strata were given a curve of less radius than ordinary, were especially favourable to the production of fissures.

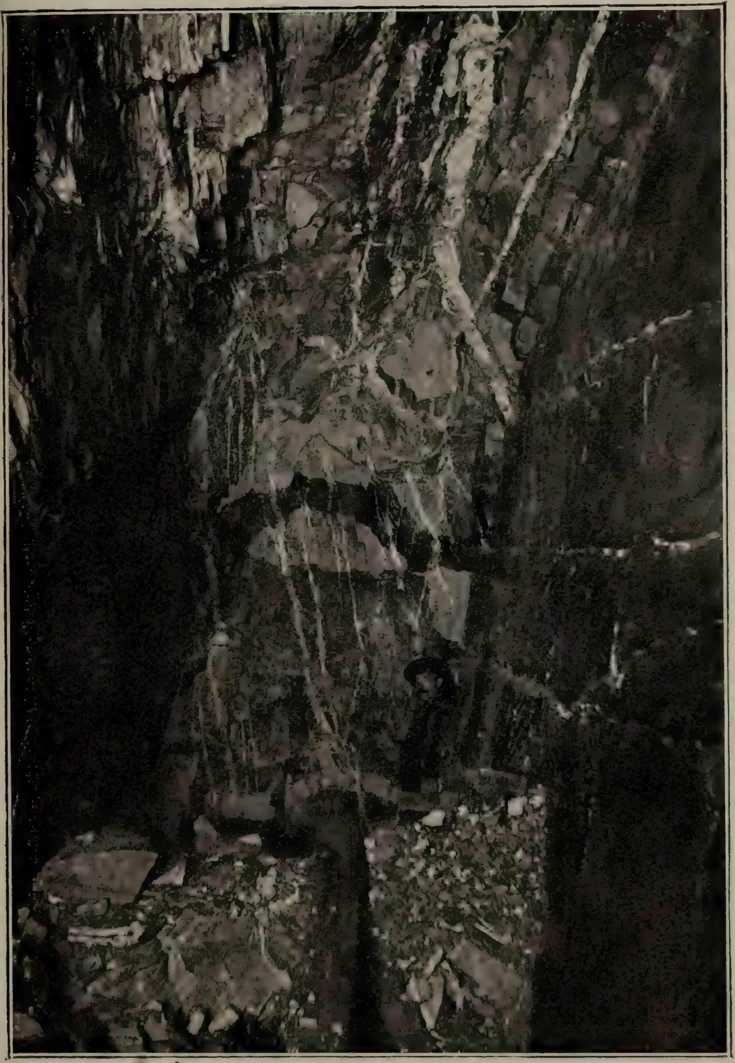
The process of folding was long continued and the deposition of vein matter probably took place during the process. Small fissures were formed along the bedding planes and filled with quartz only to be followed by other parallel openings between the quartz sheet and the slate and further precipitation of quartz in the new openings. Films of slate adhering to the quartz forming the wall of the new fissure thus became embedded in the vein. A succession

Anticlinal portion of the Borden vein on a subordinate fold corrugated in slate between beds of quartzite. West Lake mine; Mount Uniacke, N.S.

of such events produced the laminated character of the interstratified veins. It is also probable that in many cases the quartz was deposited in the slate along a number of parallel planes lying close together in an area of minimum pressure and that the quartz films increased in thickness through a widening of the spaces either by the folding of the strata or by metasomatic replacement.

The origin of the corrugations is more difficult of explanation. That they are dependent on the rock folding is generally conceded and the following explanation has been adduced:—Many veins were formed long before the folding process was completed and during the subsequent stages they were subjected to the same forces as the rocks. The main forces that produced the folding were horizontal, and if the horizontal forces be resolved into components perpendicular to and tangent to the bedding plane, the component perpendicular to the bed will be greater on the limb than at or near the apex of the anticline. There will thus be a tendency towards a thinning of the beds on the limbs and a proportionate thickening at and near the apex. This will express itself in a motion of the more plastic beds, that is of the shales or slates, from the limbs towards the apex resulting in a thickening on the latter, a phenomenon that is frequently observed especially in closely folded strata. Any quartz vein already formed in such slate will partake of the same lateral motion; on the limbs of the fold where the strata are not curved they will suffer little change, but where the strata begin to curve and the slate beds to thicken, the veins will begin to fold and produce corrugations. On the side of long domes there was but one deforming force that came prominently into play, that which produced the east and west folding, and the corrugations are consequently horizontal and parallel to the axis; but at the pitch of the dome a second force about at right angles to the first expressed itself in the pitching of the dome, the resulting movement was more complex, and corrugation was produced radiating more or less from the centre of the dome.

This theory of the origin of corrugations would also account for the different degree of crenulation often exhibited by different veins intercalated between the beds composing one single slate belt; the more corrugated veins being generally older than less corrugated ones. The quartz appears to have become plastic under the enormous



North lode at the 200-foot level, 20 feet above the syncline of a subordinate fold, made up of angulars entering from the foot-wall along the cleavage plane.
Dufferin mine, N.S., 1904.

pressure, and the deformation may have been effected by the slow flowing of particle over particle. The change in form may, however, have been brought about by the slow process of solution and reprecipitation ; if this be so it would indicate the existence of slow folding processes extending over a long period of time. The contorted broken quartz of some belts suggests that in some places the motion was too rapid to admit of the veins maintaining their continuity either by flow or by solution and reprecipitation.

The origin of some of the small crenulations which are often observed in many interstratified veins and in a few cross veins having a thickness less than one inch, is probably due to a slight motion along the numerous cleavage planes during the folding process at stages subsequent to the deposition of the veins, for these crenulations are often found to coincide with the intersection of the cleavage with the bedding plane. It is also possible that some of the larger corrugations are the result of the combined motion of the slate beds from the limbs towards the apex and that of the wall-rock along the cleavage planes.

The bulk of the evidence shows that the veins were filled by ascending solutions of a deep-seated origin. These found a passage upward through the fractured portions of the domes. A fracturing across the bedding as well as fissuring along the bedding planes seems to have been necessary for the formation of veins and ore deposits: veins are not commonly found along straight non-pitching anticlines although there was, no doubt, a great deal of fissuring along the bedding planes; on the other hand, where the anticlines pitch and the rocks were fractured across the bedding, veins are abundant. The cross fractures are themselves filled with quartz forming the angulars entering and leaving the interbedded veins. The cross fractures seem therefore, to have provided channels for the passage of solutions across the beds of quartzite and slate to the interbedded fissures along which deposition took place. That the solutions entered by way of the angulars is borne out by the fact that the rich portions of interbedded veins are those portions lying between the line of entrance of an angular and the line along which it leaves the main lead.

The source of the ascending solutions is not known, but it is held not to be in the granite or any other known igneous intrusion. Field evidence goes to show that the

granite intrusion was later than the formation of the veins. At different places, interbedded veins are cut across and sometimes along their courses, by dykes of granite, and the proximity of the intrusion appears to have had no effect on the size or richness of the veins.

Another evidence that the veins were formed prior to the granite intrusion is the complete absence of any disturbance or irregularity of the structures of the anticlinal folds and more especially of the domes at granite contacts. This proves that the granite intrusion took place at a time when the folding and doming of the quartzite and slate, as well as the deposition of the veins resulting thereof, were completed, otherwise the movements and slipping of the beds which produced them would be manifested by disturbances or faults along the line of the granite contact. At Mooseland, on the western end of the dome, interbedded quartz veins have been traced continuously to the granite, without increase in size or other irregularity of structure, but they gradually become more crystalline and finally disappear at the contact where they are apparently absorbed by the granite, like the containing metamorphosed quartzite and slate.

The observations of Prest in the western part of the province give still further evidence leading to the same conclusion. He reports that at Bear River no disturbance was observed in the structure of the Nictaux-Torbrook rocks at the granite contact, and as these rocks are conformably folded with the Goldbearing rocks, he concludes also that the folding partaken of by both series must have been nearly complete before the granite intrusion; and further, as the Nictaux-Torbrook rocks are Oriskany, the folding and the quartz veins of the Goldbearing rocks would be later than Oriskany. Then, as the granite intrusion was earlier than the Horton series, which is referable to late Devonian or Lower Carboniferous, the folding and the deposition of the quartz must have taken place during Devonian time, but earlier than the granite intrusion. Finally, at Gay's river a conglomerate of Lower Carboniferous age, largely made up of fragments eroded from the Goldbearing slate, has been mined for gold. The deposition of the gold in the Goldbearing rocks must then have commenced before the Carboniferous that is to say, during Devonian time.

It is probable that small additional layers of quartz and some gold may have been added to the gold-bearing leads, during and after the granite intrusion but, so far as known, this has not been proved by observation in the field.

Little study has been given to the cause of the precipitation of the metallic contents of the veins. The ascending thermal solutions were no doubt subjected to different chemical and physical conditions, but it is difficult to surmise what these were and what has been their effect. Some factors that may have entered in the problem are, (1) decrease of pressure that the solutions underwent on entering the fissure, (2) lowering of temperature, (3) effect of other solutions originating from below or from the earth's surface, and (4) effect of certain solid contents in the rocks. Certain slates apparently exercised a greater precipitating effect than others. These are generally black and are frequently impregnated with arsenopyrite, pyrite or pyrrhotite, and the interstratified veins that can be worked with profit are usually found in beds of this character. In some cases the cross veins also are found to be enriched where they lie in contact with strata of this class.

The question of secondary enrichment has received little study and little is known with regard to what extent the fracture zones of the districts have afforded means for the passage of meteoric waters and a secondary redistribution of the mineral contents of the veins.

Briefly stated, the observed facts seem to be best explained on the theory that the veins are epigenetic, that they were formed by the deposition of quartz, sulphides and gold in cross fractures and interbedded openings occurring chiefly in the black or pyritous slate beds of the Goldenville formation, that the conditons necessary for the formation of the veins were a great deal of fracturing across the bedding planes, permitting the passage of ascending thermal solutions and that these fractures were produced where the two horizontal orogenic forces manifested themselves in the formation of domes or the pitching of the anticlines.

PRODUCTION.

Gold was discovered in Nova Scotia in 1860, and mining operations then commenced. Two years after the discovery, gold valued at nearly $142,000 was recovered from

the quartz veins, and since that time the annual production has, with the exception of three years, fluctuated between $200,000 and $628,000, nearly attaining the latter figure in 1902.

The total production of gold in Nova Scotia from 1862 to 1912 inclusive, was 936,499 ounces recovered from 2,117,639 tons of ore mined, this productiom having a value (at $19.00 per ounce) of $17,793,481, equalling an average recovery of $8.40 per ton of ore crushed.

BIBLIOGRAPHY.

1. Faribault, E. R. Report on the Lower Cambrian rocks of Guysborough and Halifax counties, Nova Scotia: Geol. Surv. of Can., No. 243, Part P., Vol. II, 1886.

2. Dawson, J. W. Acadian Geology. The geology of Nova Scotia, New Brunswick and Prince Edward Island: Fourth edition, London, 1891 (First edition 1855).

3. Woodman, J. E. Studies in the gold-bearing slates of Nova Scotia: Proc. Boston Soc. of Nat. Hist., Vol. 28, No. 15, pp. 375-407, Boston, 1899.

4. Faribault, E. R. On the gold-measures of Nova Scotia and deep mining: Jour. Can. Min. Inst., Vol. II, pp. 119-128, 1899.

5. Faribault, E. R. Deep gold mining in Nova Scotia: Report to the Government of Nova Scotia, Halifax, 1903.

6. Woodman, J. E. The sediments of the Meguma (Goldbearing) Series of Nova Scotia: Am. Geologist, Vol. XXXIV, pp. 13-34, 1904.

7. Woodman, J. E. Geology of the Moose River Gold District, Halifax county, Nova Scotia: Proc. and Trans. N. S. Inst. of Sc., Vol. XI, Part I, pp. 18-88, 1904.

8. Woodman, J. E. Probable age of the Meguma (Gold-bearing) Series of Nova Scotia: Bull. Geol. Soc. of Am., Vol. XIX, pp. 99-112, 1908.

9. Rickard, T. A. The Domes of Nova Scotia: Jour. Can. Min. Inst., Vol. XV., 1912.

10. Faribault, E. R. Annual Summary Reports on the Goldbearing rocks of Nova Scotia, 1897 to the present; Serial geological maps of the Goldbearing rocks of Nova Scotia, from Canso to St. Margarets bay and Windsor; Plans and sections of gold mining districts of Nova Scotia: Published by the Geological Survey of Canada.

11. Malcolm, W. Gold fields of Nova Scotia. Compiled largely from the results of investigations by E. R. Faribault: Geol. Surv. of Can., Memoir No. 20, 1913.

A complete bibliography of the literature of the Gold-bearing series of Nova Scotia is contained in the last paper cited, namely, "Gold Fields of Nova Scotia": Geol. Surv. of Canada, Memoir No. 20, 1913, by W, Malcolm.

OLDHAM GOLD DISTRICT.*

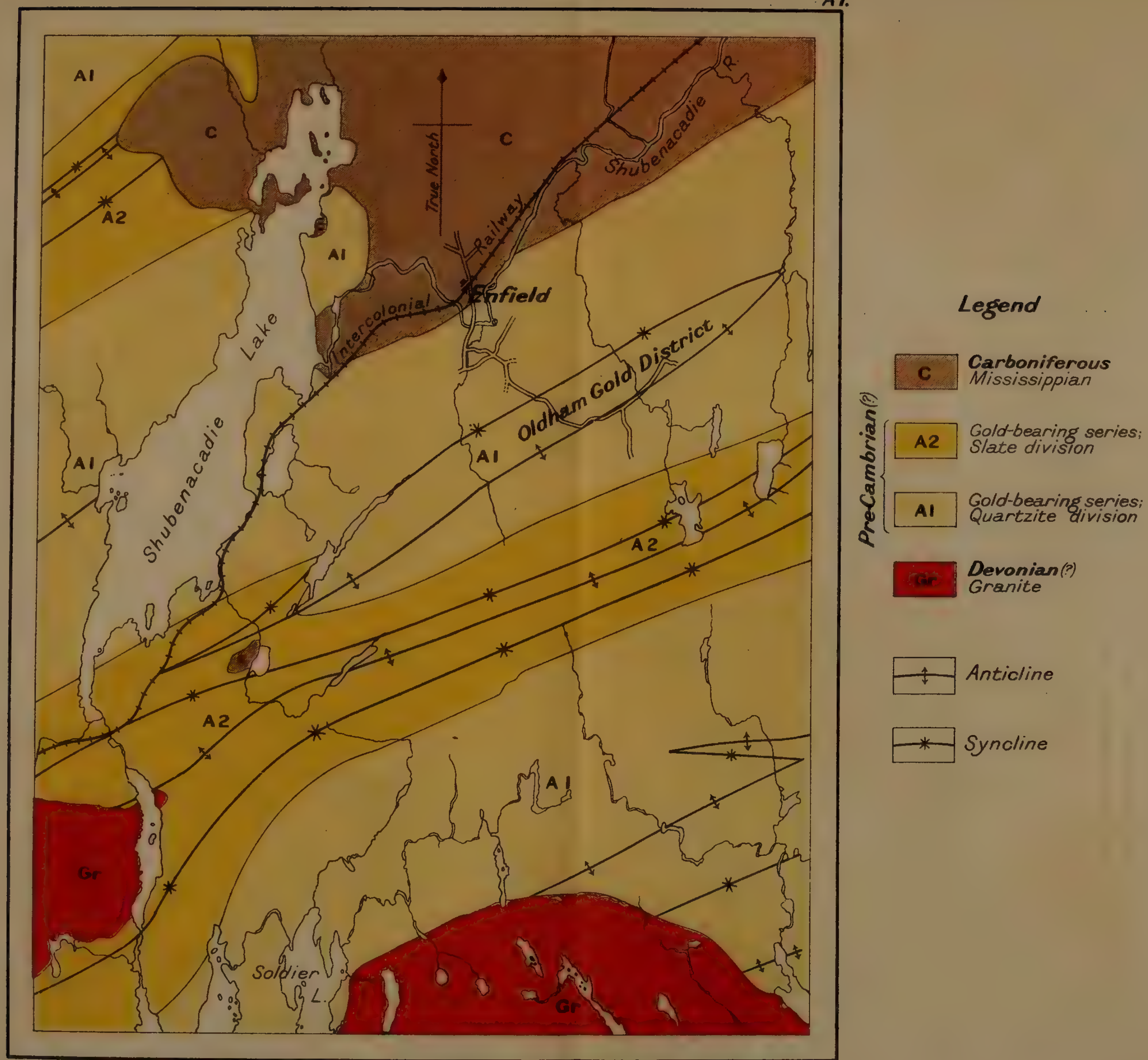
(E. R. Faribault.)

INTRODUCTION.

LOCATION.

Oldham gold district is situated in the northern part of Halifax county about 25 miles (40 km.) north of the city of Halifax and 3 miles (4·8 km.) southeast of Enfield, a small station on the Intercolonial railway. The district lies near the summit of the watershed that separates the streams flowing south through Porters lakes into the Atlantic from those whose waters reach the Bay of Fundy

*See Map—Oldham Gold District and Vicinity.



Geological Survey, Canada.

Oldham Gold District and **Vicinity**

Miles
1 ½ 0 1 2 3 4
Kilometres
1 ½ 0 1 2 3 4 5

by the Shubenacadie river. The altitude of the centre of the district is 317 feet (96·6 m.).

GEOLOGY.

The quartzites and slates constituting the Goldenville formation of the Goldbearing series (Pre-Cambrian) are here exposed in a subordinate anticline 9 miles (14·5 km.) long lying on the south limb of the Shubenacadie - Grand lake anticline. The distance between the two anticlines is a little over two miles (3·2 km.) and the intervening syncline lies half a mile (0·8 km.) north of the Oldham anticline.

The fold which follows a ridge running east and west is transversely symmetrical, the strata dip on both limbs at angles varying from 50° to 75°, and the axial plane is nearly vertical. The fold pitches to the east at angles increasing to 45°, but two miles (3·2 km.) east of the centre of the district, flattens out and disappears by meeting the syncline on the north; it pitches to the west at an angle great enough to completely conceal the Goldenville formation by the Halifax slate formation at a distance of 5 miles (8 km.) west, and finally dies out also by joining the syncline two miles (3·2 km.) farther at Wellington station.

The anticlinal fold thus forms a long and narrow elliptical dome pitching to the east and west. In the western part of the dome the strata on both limbs run nearly parallel with the axis of the anticline, but finally converge and curve sharply within 10 feet (3 m.) over the apex; towards the east the fold becomes gradually broader and the strata form nearly concentric curves.

The horizon of the quartzites and slates of the Goldenville formation exposed on the dome is estimated to be 4,560 feet (1,390 m.) below the base of the Halifax slate formation, and as the thickness cf the latter formation is 11,700 feet (3,566 m.), a total thickness of over 16,260 feet (4,956 m.) of strata has been eroded off the dome.

The dome has suffered much faulting especially in the eastern part. An important fault follows the axis of the anticline from the centre of the dome eastward, and attempts to trace veins around the apex of the dome past the fault have met with poor success. Radiating from the dome towards the southeast is a series of important faults, two of which have horizontal displacements of 112 and 124 feet (44

and 38 m.) respectively. On the north limb are a few small breaks. A few flat faults having the nature of thrusts have also been met in underground workings. The faults do not continue for great distance on the strike nor in depth and are later than the formation of the veins, but the Baker vein in the eastern part of the district occupies a fault plane cutting the anticline at right angles which is of earlier origin and probably greater extent in depth than the other faults.

CHARACTER OF THE GOLD DEPOSITS.

With the exception of the Baker vein which has been proved highly auriferous, all the veins worked in the district are of the interbedded type and are called leads. They follow fractures or slips along stratification planes and occur chiefly in beds of slate interstratified between beds of quartzite. The outcrops of the veins form almost complete concentric ellipses curving sharply at the western end and broadly at the eastern end of the dome. Over 25 interbedded veins have been worked and traced more or less continuously on both the north and south limbs of the dome. The vein-bearing zone is thus confined to the dome, on which it extends 8,100 feet (2,470 m.) east and west along the anticlinal fold and 1,600 feet (485 m.) across it.

The most productive part of the district is the eastern end of the dome, where the pitch of the anticline increases rapidly from 0° to 45°, causing there the maximum amount of fracturing across and along the stratification plane which produced rolls, corrugations and angulars favourable to ore deposition.

Amongst the most important interbedded veins may be mentioned the Dunbrack, Sterling, Boston-Oldham, North Wallace, South Wallace, and Donaldson. A great number of others have been worked and many of them with profit.

The most important ore-shoots follow the rolls, which are quite prominent in the veins in the southeastern part of the district and pitch to the east at approximately the same angle as that of the pitch of the anticline. On the Dunbrack lead a very persistent and rich ore-shoot was worked to a depth estimated at 1,200 feet (356 m.) on a pitch increasing gradually from 5° to 40°. The rich ore-shoot which in 1909 averaged 2·88 ounces of gold per ton in the Sterling Barrel lead on the apex of the anticline has been

worked to a depth of 1,610 feet (490 m.) on a dip varying from 30° at the surface to 43° at a vertical depth of about 900 feet (275 m.). This is the deepest mine on an interbedded vein in Nova Scotia.

In the northeastern part of the dome a number of veins such as the Boston-Oldham and Frankfort proved rich on their curve towards the apex of the anticline. Some veins have been worked extensively on the strike but to shallow depth.

North of the centre of the dome, several leads were enriched and thickened at the intersection of angulars entering obliquely from the southwest or footwall side and leaving on the northeast. The enriched and thickened part of a lead comprised between the point of entrance of an angular and that of leaving, is generally less than 20 feet (6 m.) in length and 100 feet (30 m.) in depth, forming a small ore-shoot called gold or pay-streak. Several very rich gold-streaks have thus been formed on the Blue, Hall and other leads where intersected by the Britannia angular, the ore yielding from 1 to 100 ounces of gold per ton.

In the northwestern and southwestern part of the dome a few leads have also been enriched at the intersection of angulars coming in on the footwall side from the southwest and northeast respectively. In the Blackie vein the gold was concentrated in arsenopyrite pockets, some of which carried as much as 5 to 7 ounces of precious metal, and outside of these the vein had little or no value.

In 1892, J. E. Hardman, manager for the Napier company, sank a vertical shaft 113 feet (35 m.) deep on the anticline on Area 102, cutting at the apex seven superimposed saddle-veins that do not outcrop at the surface. Two of these were sufficiently auriferous to justify further development. This and similar developments in other districts point to the existence of a pay-zone extending to a considerable depth in which a succession of auriferous, interbedded, quartz veins of similar character and extent lies superimposed one above the other.

At a short distance west of Hardman's vertical shaft the Harrison, South Ohio and some other adjacent veins are thickened several times their usual size on the apex of the anticline where they curve sharply within 10 feet (3 m.) and form ore-shoots pitching west about 20°.

In the Hay lead lying outside of the district, 1,800 feet (550 m.) north of the anticline, an isolated pocket carrying

60 ounces of gold was found at the intersection of an angular with the main lead.

A pocket of 100 pounds of reddish scheelite was found at the depth of 40 feet (12 m.) in a large roll of quartz in the Schaffer Barrel lead on the eastern pitch of the anticline, where good examples of barrel quartz structure can be observed at the surface. Smaller pockets are also reported to have been found in the South Wallace, Dunbrack and a few other veins. Until recently the mineral was not identified by the miners who called it pinkeye, and as gold is not found associated with it they shunned its presence.

PRODUCTION.

Gold was first discovered in this district in 1861. Active mining operations commenced the following year and have continued steadily to the present time. The official reports show that the yearly production of gold fluctuated between 282 ounces in 1897 and 3,171 ounces (for 9 months) in 1893, and the average yield per ton varied from 10 dwt. 21 gr. in 1881 to 3 oz. 5 dwt. 5 gr. in 1908.

The total gold production from 1862 to 1912 has been 67,343 ounces, valued at $1,279,520, extracted from 58,735 tons of ore. The average yield per ton is therefore 1 oz. 2 dwt. 22 gr.

ANNOTATED GUIDE: ENFIELD TO WESTERN END OF OLDHAM GOLD DISTRICT.

Miles and Kilometres.	
0 m. 0 km.	**Enfield Station**—Alt. 63 ft. (19·2 m.). Going in a southerly direction from Enfield station, the road runs for the first half a mile over flat-lying Lower Carboniferous sediments consisting chiefly of thick deposits of gypsum and beds of limestone, sandstone and shale which are here concealed by boulder clay and deposits of sands and clays of Pleistocene age.
0·5 m. 0·8 km.	**Shubenacadie River**—Alt. 47 ft. (14·3 m.). At the Shubenacadie river the road enters the Goldenville formation of the Goldbearing

Miles and Kilometres.

series, an area of Pre-Cambrian rocks which extends southward to the Altantic. For the first mile and a half, an ascending section of alternating beds of quartzite and shale, striking east and west, and dipping south at high angles, is traversed to a point 400 feet (120 m.) north of Lily lake, where the intervening syncline between the Shubenacadie-Grand lake anticline and the Oldham anticline is crossed and can be located a short distance on left by several outcrops of quartzite curving on the western plunge of the fold.

2·5 m. 4·0 km. **Horn Brook**—Alt. 247 ft. (75·3 m.). In the next half mile the same strata are again crossed but in descending order, to the Oldham anticline which crosses Horn brook 100 feet (30 m.) above the fall on the right. The Dowell lead may be observed on the left in an open-cut 200 feet (60 m.) north of the fall.

ANNOTATED GUIDE: OLDHAM GOLD DISTRICT.

(See plan and sections of Oldham Gold District).

Feet and Metres.

0 ft. 0 m. **Horn Brook**—Alt. 247 ft. (75·3 m.). From Horn brook at the western extremity of the district, the anticline strikes easterly along a ridge which is followed by the road as far as Black brook. Going easterly along the road, the following observations may be made reckoning the distances in feet from Horn brook.

1,500 ft. 457 m. Anticline exposed crossing road obliquely from right to left; apex plunges west about 20°; strata curve and dip north and south at low angles increasing rapidly to 70° to form a transversely symmetrical and sharp fold. Cleavage is perpendicular.

1,700 ft. 518 m. North of road 65 feet (20 m.) the South Ohio lead dipping south 43° and the Richey lead dipping north 35° follow the stratification and converge towards the west and in a sharp

Feet and Metres.

curve on the anticline to form one saddle-vein, the apex of which plunges westward about 20°. An ore-shoot on the apex containing arsenopyrite and galena 20 to 24 inches thick was worked only for a short distance on the pitch.

2,330 ft. 710 m. North of road 90 feet (27 m.): Harrison lead dipping north 55° curves conformably with the strata within 10 feet on anticline and forms another ore-shoot at the apex pitching westward about 20° and underlying the South Ohio-Richey ore-shoot; much galena; angulars entering from footwall side have thickened the lead at the apex. On both the north and the south limb of the anticline, a series of 25 interbedded and parallel veins outcrops within a distance of 800 feet (24·5 m.) which is the width of the auriferous quartz zone on each side of the axis; the two series of veins converge towards the west; several short ore-shoots called gold-streaks have been found in these veins, particularly on the north limb, at the intersection of angulars entering on the foot-wall side from the southwest on the north limb and from the northeast on the south limb.

2,590 ft. 789 m. North of the road 60 feet (18 m.): J. E. Hardman's vertical shaft 113 feet (42·5 m.) deep sunk on the axis of the anticline cut seven superimposed saddle-veins, both legs of which were intersected at a depth of 100 feet (30 m.) by cross-cuts driven 100 feet each way, showing the continuance of the saddle-veins to that depth and their conformity to the structure of the fold.

3,320 ft. 1,010 m. Alt. 313 ft. (95·3 m.). Goff's road leads off to right: centre of dome is reached; the anticline crosses from left to right and passes between the road and the school house, where beds of quartzite and slate are exposed lying horizontally along the apex and overlying the crest of a rich corrugated saddle-vein which

Feet and Metres.

was worked to some depth on both legs; the vertical cleavage is strongly developed even in the quartzite, and indicates the exact direction of the anticline; the intersection of the cleavage and bedding planes is at right angles indicating the centre of the dome. Large barren veins of coarse white quartz cross the anticline at right angles, and are probably the result of the arching of the fold producing the east and west pitch. At the foot of the hill, 125 feet (38 m.) north of the anticline, the footwall of a small lead adjacent to the Harrison lead dips north 65° and is also intersected by the same large cross veins; the lead is largely made up and enriched by very small angulars entering from the footwall side, but is not affected by the large cross veins. The strata and interbedded veins on both limbs strike parallel with the axis of the anticline.

4,090 ft. 1,247 m. Road runs downhill: close by on the right the footwall of the Morell lead curves slightly and dips north 57°; corrugations on the footwall caused by the intersection of cleavage and bedding planes pitch easterly at a low angle indicating the pitch of the dome. On the footwall is a fault having a horizontal displacement of 15 inches.

4,345 ft. 1,313 m. Close by on the left is W. A. Brennan's stamp-mill with 2 batteries and amalgamating tables, one Wilfley concentrating table, water-power. Footwall of a vein dips north 52°, corrugations pitch east.

4,540 ft. 1,383 m. **Black Brook**—Alt. 244 ft. (74·3 m.). J. E. Hardman's old stamp mill on the right, with 2 batteries and amalgamating tables, water-power and Pelton wheel, has produced probably more than half the gold extracted from the Oldham deposits. On the east side of Black brook, opposite the mill, a good section of the anticlinal fold is exposed where superimposed beds of quartzite and slate curve broadly on the apex; between a bed of slate and quartzite is intercalated a small vein, deeply corrugated, showing gold at the point of intersection of an

Feet and Metres.

angular. Vertical cleavage is strongly developed in the quartzite, the slipping along the cleavage plane having produced the corrugations, the slate besides being cleaved shows a sympathetic folding with the corrugations of the veins; the corrugations pitch eastward in the same direction as the pitch of the anticline. From Black brook eastward the pitch of the anticline increases gradually to 45°, the fold becomes broader and the strata describe large and almost concentric curves. Several faults radiate toward the east and southeast, the largest one following approximately the anticlinal axis.

Going easterly from Black brook over the hill in the direction of the anticline the following observations may be made.

4,790 ft. 1,460 m. At the top of the hill, on the south limb, the Carpenter lead curves in the shape of an S in a subordinate crumple of the strata, 14 feet wide, pitching east about 30°; the crumpled part of the lead is enriched and enlarged from 3 inches to 24 inches by angulars entering from below and forming a rich ore-shoot which was worked out to the depth of 200 feet (60 m.). The adjoining strata are conformably crumpled.

Farther east, the Galena, Boston-Oldham and other leads are crossed in open-cuts on the north limb of the fold where they curve to the anticlinal fault, on the south side of which they have not been identified.

5,840 ft. 1,790 m. On the Sterling Barrel lead, a rich ore-shoot has been worked to a depth of 1,610 feet (487 m.) by an inclined shaft on a dip increasing from 30° at the surface to 43° at a vertical depth of about 900 feet (275 m.); the ore-shoot occurs immediately south of the anticlinal fault, where the strata form a pronounced bulge or undulation of small horizontal width, but of great extent in depth; the structure and character of the shoot was very regular from the surface to the bottom of the workings, its horizontal length varying from 100 to 150 feet (30 to 45 m.). The vein is corrugated, lies on the lower side of

Feet and Metres.

a bed of black slate and is often "frozen" to quartzite footwall in which the corrugations sink and form furrows.

Corrugations of the same character are well exposed 400 feet (120 m.) further east on the footwall of a shaft on the Rusty lead, which dips, 31° east and is supposed to be the continuation of the Sterling Barrel lead on the north side of the anticlinal fault.

Looking north from the top of the dump of the Sterling Barrel mine a good general view may be had of the workings along the outcrops of the veins, showing the curvature of the north-eastern part of the dome.

From this point the road follows in a north-easterly direction, crossing successively the North Wallace, Rusty, Rutherford and Frankfort leads where they are worked more or less along their outcrops by open-cuts and shafts. A branch road to the southeast is then followed along and across the Blue lead, to the Schaffer Barrel lead. The Schaffer Barrel lead has here been worked to a depth of 200 feet (60 m.) and southward along the outcrop as far as the anticlinal fault. The quartzite footwall striking south on a broad curve and dipping east 45° is much corrugated in deep furrows; the furrows pitch eastward and occur along the line of intersection of cleavage and bedding planes and are apparently formed by the vertical movements of the rock along the cleavage planes. The vein and enclosing slate are crumpled into a series of corrugations or barrels conformable with the furrows. South of the shaft a pocket carrying 100 pounds of reddish scheelite associated with ankerite was found in the vein at the depth of 40 feet (12 m.) in a large roll of quartz. The Schaffer Barrel lead has a horizontal displacement of 150 feet (45 m.) on the anticlinal fault, 124 feet (37·6 m.) on the Whitehead fault and 112 feet (34 m.) on the next one south.

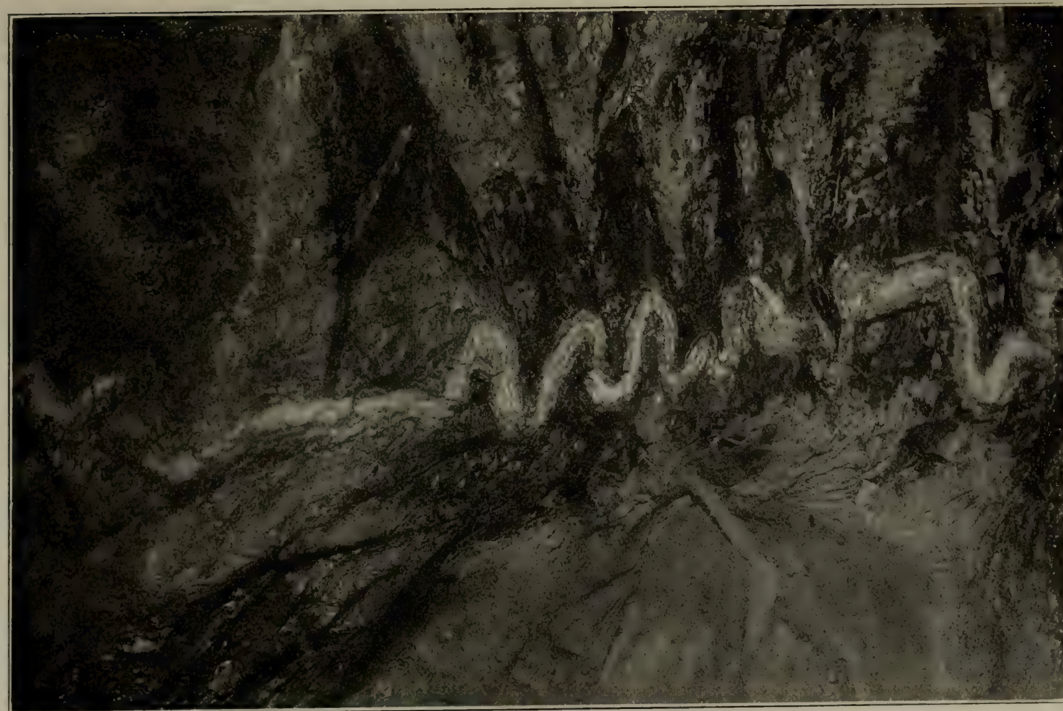
For a third of a mile farther east, a few other interbedded veins occur on the eastern pitch

Feet and Metres.

of the dome, but none have been very productive. The Baker vein, a quarter of a mile east, is, however, of especial interest as being the only one in the district that crosses the stratification for any considerable length and has proved very productive. It lies in a fault-plane which cuts the anticline at right angles, and, unlike the interbedded veins, it has much gouge and is very irregular in thickness and crooked in strike, The average thickness of the vein is 18 inches (0·45 m.), and the average yield of the ore 5 to 7 dwts. Several 100-ton lots gave $1\frac{1}{2}$ to 2 ounces. The vein cannot now be seen at the surface.

The Hardman mine is on the Dunbrack lead in a westerly direction from the Schaffer Barrel lead across the anticline. This lead lies on the footwall side of a bed of slate interstratified with quartzite dipping southeast 43° Apart from the rolls, the thickness of the vein varies from a fraction of an inch to 8 inches and may average 4 inches. The vein is corrugated and the corrugations pitch east 38° like those directly north on the footwall of the Schaffer Barrel lead. Two well-defined and parallel ore-shoots or rolls have been worked in the lead, the Ned McDonnell shoot and the Hardman shoot, pitching east at a lower angle than that of the corrugations. The upper one, the Ned McDonnell shoot, does not quite reach the surface but was worked for a length of about 850 feet (259 m.) on the pitch to the first fault of 112 feet (34 m.), beyond which it has not yet been discovered. The quartz and slate measured in vertical section 8 inches in thickness and 9 feet in breadth, having been thickened and enriched by small angulars entering from the footwall side.

The Hardman ore-shoot, which was probably the richest one worked in the province, lies about 140 feet (42 m.) below the Ned McDonnell roll and runs parallel with it. It does not reach the surface, but lies at a depth of about 175 feet, and a little east of the western end of the Ned McDonnell roll, where it originates like the latter



Hardman ore-shoot in the Dunbrack vein, showing section and top of corrugations. Oldham, N.S. 1897.

Feet and Metres.

in a small roll increasing in size and value as it pitches 5° to 40°. It has been worked continuously on the pitch for about 1,200 feet (365 m.) across the first fault and as far east as the Whitehead fault beyond which it probably extends farther but has not yet been discovered. On the first fault the roll has an upthrow of about 130 feet (39 m.) and a horizontal displacement to the south of 112 feet (34 m.). The thickness of the vein above and below the roll averages 4 inches, whereas it increases in the roll and varies from 8 to 22 inches and may average 17 inches. In the roll the quartz and enclosing slate have a decided rolly structure, and vertical sections of the roll have the form of an elongated ellipse, the length or height of which varies from 8 to 18 feet. Small angulars of quartz, sometimes associated with siderite and seldom over an inch in width, branch off from the roll into the quartzite foot and hanging walls. Angulars entering the roll from the hanging-wall had little or no effect on the richness of the ore, but those from the footwall side were decided feeders or enlargers of the quartz above them. It is important to note that the vein dips steeper below the roll than above it, producing a decided flexure of the strata which may account for the formation of the roll and the angulars during the folding process and the consequent slipping upward of one bed upon another. Outside of the roll the ore had a general assay value of 3 to 15 dwt. (or $3 to $15) per ton in free gold, whereas the ore of the Hardman roll itself never yielded less than one ounce per ton, most of it gave 9 to 30 ounces, and sometimes as much as 80 ounces ($1,600) per ton for lots of 8 to 10 tons. The high grade ore was associated with galena and zincblende, the poorer quartz carrying from 1½ to 2 per cent of arsenopyrite, pyrite and pyrrhotite, all of these minerals being found also in the rich ore but subordinate in amount to the galena and blende.

Following the road out from Hardman's mine the southeastern part of the dome is traversed in a northerly direction to the anticline. First the Dunbrack, Schaffer Barrel and Ned McDonnell leads are successively crossed where they originate between the strata as these strata begin to curve to the northeast and to dip at lower angles towards the anticline, accompanied with a development of corrugations on the footwall. Then, from the Sterling Barrel lead to the anticline the strata curve more rapidly and the interbedded veins become more numerous and are greatly thickened by large barren 'bull' veins. The original structure of the strata and interbedded veins is, however, much disturbed by the faults radiating from the centre of the dome towards the southeast.

ANNOTATED GUIDE.

ENFIELD TO TRURO.

(G. A. YOUNG.)

Miles and Kilometres.

0 m.
0 km. **Enfield**—Alt. 63 ft. (19·2 m.). Beyond Enfield the railway alternately approaches to and recedes from the Shubenacadie river. To the southeast, beyond the river rises a somewhat broken hilly country underlain by the rocks of the Goldbearing series. The Carboniferous area stretching to the north is lower and only gently undulating. Rock exposures are comparatively rare over the Carboniferous area but the presence, in many localities, of beds of gypsum and limestone indicates that the strata belong to the Windsor series. The beds are faulted and dip in various directions but usually at comparatively low angles.

12·4 m.
19·9 km. **Shubenacadie Station**—Alt. 66 ft. (20·1 m.). The boundary between the area underlain by the Carboniferous strata and that occupied by the rocks of the Goldbearing series lies about 4 miles (6·4 km.) to the east. There the basal members of the Carboniferous are conglomerates and sandstones which in places contained sufficient alluvial gold to warrant mining. The

Miles and Kilometres.

source of the gold was, undoubtedly, the quartz veins of the underlying Goldbearing series.

Just beyond Shubenacadie station the railway crosses to the east side of Shubenacadie river and for upwards of a mile runs in view of the winding river. Beyond this point the railway gradually passes away from the river.

16·9 m.
27·2 km.

Stewiacke Station—Alt. 86 ft. (26·2 m.). Beyond this station the railway approaches the banks of Stewiacke river, a westerly flowing tributary of Shubenacadie river. About 1½ miles (2·4 km.) beyond, the railway crosses the Stewiacke river and there leaves the valley of this river. The Stewiacke river drains a wide expanse of gently undulating country stretching far to the eastward and underlain by Carboniferous measures belonging to the Windsor series.

26 m.
41·8 km.

Brookfield Station—Alt. 102 ft. (31·1 m.). Brookfield is situated near the northern boundary of the broad area of Carboniferous strata (Windsor series) crossed by the railway after leaving the region underlain by the Goldbearing series. In the districts about Brookfield, the Windsor beds dip in various directions at all angles.

Three quarters of a mile (1·2 km.) beyond Brookfield, the railway enters a district underlain by the Union series of Devonian or possibly Carboniferous age. The country is low and gently undulatory in character. Two and one quarter miles (3·6 km.) farther, the railway crosses a low summit (altitude, 181 feet or (155·2 m.) and commences the descent of the slopes leading to the Bay of Minas.

The strata belonging to the Union series dip in various directions at angles ranging from vertical to nearly horizontal. As in the case of the Windsor beds to the south, there is a general tendency for the strikes of the strata to pursue an easterly course. Presumably both groups of strata are closely folded along east-west axes and probably they are much faulted.

Miles and Kilometres.

On stratigraphical grounds, Fletcher concluded that the Union beds underlie the Windsor strata and therefore he considered them to be of Devonian age. In neighbouring districts, however, the Union and associated strata carry a flora of mid-Carboniferous (Millstone Grit?) age.

As the railway descends to the valley of Salmon river which flows westerly into the head of the Bay of Minas, the high hills of the Cobequids become visible to the north. These hills are flanked by disturbed Carboniferous strata which, in the valley of Salmon river, are overlapped by horizontal, Triassic sandstones and conglomerates. Truro is situated in the Triassic area, on the southern side of Salmon river and the boundary between the highly disturbed Union beds and the undisturbed Triassic, passes through the southern outskirts of the town.

34 m. 54·7 km. **Truro**—Alt. 60 ft. (18·3 m.).

GUIDE BOOK No. 1

EXCURSION

IN

Eastern Quebec and the Maritime Provinces

(EXCURSION A 1.)

PART II

ISSUED BY THE GEOLOGICAL SURVEY

R. OTTAWA
GOVERNMENT PRINTING BUREAU
1913

35063—1 A

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THE RIVERSDALE–UNION GROUP AT TRURO AND IN THE TYPE SECTION ALONG THE INTERCOLONIAL RAILWAY EAST OF TRURO.*

INTRODUCTION.

(G. A. Young.)

The interest attached to the Riversdale–Union series does not lie directly in the structures presented by these measures nor in the characters of the faunas or floras they may carry. It arises from the fact that though this series locally at least, is as much as 10,000 feet (3,050 m.) thick, apparently is widely displayed over a considerable portion of Nova Scotia, and has been studied and mapped in detail, yet one group of geologists holds that the strata are of Devonian age while another group contends that the measures are of Carboniferous, probably Pennsylvanian, age.

The strata of the Riversdale-Union series as exposed along the Intercolonial railway eastward from Truro, occur in a band of so-called Devonian rocks which stretches continuously from Cape Breton island on the east to near Truro on the west where the band forks. One branch continues in a westerly direction along the south side of Minas basin to Horton Bluff near Windsor, the other band parallels the north shore of Minas basin and with some interruptions, extends nearly to Cape Chignecto. The length of the band from Cape Breton to Horton Bluff is about 180 miles (290 km.), in places it expands to a width of nearly 20 miles (30 km.), in other places it contracts to a breadth of only 2 or 3 miles (3–5 km.).

Throughout their whole extent, the measures have been studied by the late Hugh Fletcher and mapped by him in detail on a scale of 1 mile to 1 inch. His work shows that along the borders of the long band of these measures, the so-called Devonian is brought into contact with representatives of most of the geological divisions developed in Nova Scotia, though for many miles at a time the strata are bounded by Carboniferous beds of Mississippian age. The accompanying diagram map prepared from maps of Fletcher exhibits his conception of the geological relations

*See Map—Union–Riversdale.

of a portion of the Riversdale-Union area in a region from which considerable palæontological evidence is forthcoming to indicate that the strata are not of Devonian age but are approximately the equivalents of the Millstone Grit and therefore of Upper Carboniferous or Pennsylvanian age.

For various reasons Fletcher in working out structural details made little or no use of fossils but instead depended solely on stratigraphical methods, and in making correlations was guided almost entirely by structural and lithological characters. Furthermore, during the course of his long life work, as he extended his mapping from the extremity of Cape Breton on the east to and over the Carboniferous areas of the mainland, his views regarding the classification of the Carboniferous changed, but yet, in deference to established custom or for other reasons, the classification as expressed on his maps remained essentially unchanged. As an instance in point, it may be noted that under the term Carboniferous Conglomerate was classed on earlier maps a thick series of coarse sediments supposed to mark the base of the Carboniferous system; on later maps, the term was made to include also a series of shales, etc., recognized as representing the Horton series; while on still later maps, the older meaning of the term Carboniferous Conglomerate was readopted and the Horton beds were mapped as Devonian. Besides the difficulty of interpreting Fletcher's maps arising from the conditions outlined above, a student is confronted with another difficulty due to the fact that if not personally acquainted with the field he is not in a position to understand why, for instance, the area of rocks indicated on the accompanying map as lying north of Riversdale and wholly enclosed by 'Devonian', was classed as Carboniferous Conglomerate, i.e. as the basal portion of the Carboniferous, and not as some higher member of the system. The explanation seems to be that Fletcher from his studies of such sections of the Carboniferous as are exposed at Sydney and Joggins, became convinced that the Carboniferous system where most fully developed, consists in ascending order of Conglomerate series, Limestone series, Millstone Grit, and Productive Coal Measures, and furthermore that the Conglomerate series was more or less local in its development and that in many places the Limestone series forms the base of the Carboniferous.

From the above view points, Fletcher made use of five main arguments to show that the Riversdale-Union and associated strata are of Devonian and not Carboniferous age as held by various palæontologists. It should be remembered that of the contending parties, Fletcher is virtually the only member who has studied the stratigraphy of the region. Fletcher held that the strata in question are of Devonian age because: (1) The measures as compared with the Carboniferous beds, are in general metamorphosed, contorted, and associated with igneous rocks generally absent from the Carboniferous areas. (2) The measures contain fossil plants, etc., of Devonian types. (3) The measures closely resemble the Little River group of St. John, N.B., which by Dawson was placed in the Devonian. (4) The measures cannot lie above the Limestone series since they are not developed in such well defined sections as those of Joggins and Sydney harbour. (5) The measures lie unconformably beneath the Carboniferous Limestone series.

As opposed to the above arguments it may be urged: (1) That, deductions based on relative degrees of metamorphism and of disturbance of the strata and on the presence or absence of igneous bodies, are not always reliable since by using such arguments, Fletcher [**5**] in the case of one area, grouped in the Devonian certain metamorphosed, disturbed, fossiliferous limestones and associated beds cut by igneous rocks but later [**6**, p. 33 and pp. 44-45; **7**], in spite of their evident metamorphism and disturbed condition, placed them with the Carboniferous and stated [**6**, p. 54] that some of the Carboniferous strata are as much altered as the so-called Devonian. (2) That, though the assemblage of varied measures grouped by Fletcher as Devonian do hold Devonian fossils in places yet this is only so because the so-called Devonian is made up of diverse elements including the fossiliferous lower Devonian of Arisaig. But the bulk of the strata, so far as the fossiliferous evidence goes, is held by palæontologists to be of Carboniferous age and to include measures representative of the Horton series at the base of the system and of horizons about equivalent to the Millstone Grit in the upper part of the system. (3) That, the bulk of the so-called Devonian may represent the Little River group of St. John, N.B., is generally conceded but though Dawson assigned the Little River group on palæontological evidence to the

Devonian, yet most palæontologists now agree that the age of the Little River group is approximately that of the Millstone Grit. Furthermore it does not appear that the stratigraphical evidence of the Devonian age of the Little River group is any more definitely proven than in the case of the Riversdale-Union series. (4) The argument that the Riversdale-Union series cannot be younger than and therefore overlie the Limestone series because of its absence from such a position in such relatively clearly developed sections as the Joggins and at Sydney, is, in part at least, met by the results of recent work by Hyde in the Sydney basin (see later pages). (5) The main argument as put forward by Fletcher, that the Riversdale-Union is unconformably overlain by the Limestone series, remains to be considered. Those who disagree with Fletcher's conclusions are forced to adopt one or more of the three following explanations. (*a*) That, Fletcher has placed together under the heading of Devonian, different groups of strata of diverse ages and that where the Limestone series unmistakably overlies 'Devonian' strata, the older measures are not the equivalent of the Riversdale-Union series. That in some instances such may be the case, is demonstrated in the instance of the Horton series near Windsor and of the lower Devonian of Arisaig both of which groups almost of a certainty unconformably underlie the Carboniferous Limestone series but are not the equivalents of the Riversdale-Union series. (*b*) That, where the Riversdale-Union is unmistakably overlain by strata of Carboniferous age, Fletcher was mistaken in correlating the overlying measures with either the Carboniferous Conglomerate or the Carboniferous Limestone. Except possibly in one instance, no independent attempt has yet been made to prove this contention. (c) That, where Riversdale- Union and members of the Mississippian are in contact, Fletcher was mistaken in regard to his interpretation of the structures. In this connection it is justifiable to point out, that though Fletcher was emphatic in his oft repeated declaration of the unconformable superposition of the Limestone series upon the Riversdale-Union, yet in no instance did he present detailed statements of the evidence of such a relation but mainly was content to assert that at various points one division unmistakably overlay the other. That mistakes of interpretation may have arisen is not an unwarranted supposition in view of the fact that the geolo-

gical structure of the region in general is admittedly intricate, and exposures at critical points are usually imperfect.

In view of the above stated lines of criticism it must be emphasized that, whatever results future study of the facts in the field may yield, in the opinion of all who have used Fletcher's maps, the boundaries laid down on them by him will be found to accurately indicate the limits of structural or stratigraphical units even though, eventually, it may be proven that errors of classification and correlation exist.

Of the geologists who have held opinions contrary to those advocated by Fletcher, nearly all have based their arguments solely on palæontological grounds. Dawson from the first held that the strata in question are of Carboniferous age and so described and mapped them in the first edition of Acadian Geology published in 1858. The following fossils have been determined by Dawson [**4**; **3**, p. 29] as occurring in the strata of the type section along the Intercolonial railway. Possibly the list as given is incomplete, since Dawson did not always record localities from which fossils were obtained.

Anthracomya (Naiadites) elongata.	Lepidophloios acadianus.
A. lævis.	Odontopteris antiqua.
Calamites cistii.	Cardiopteris,—
C. cannæformis.	Pectopteris abbreviata.
	Hymenophyllites furcatus.

From the character of the fossils, Dawson considered the containing strata to be of Millstone Grit age.

In 1897 and succeeding years, H. M. Ami visited many localities within the so-called Devonian area and made extensive collections of fossils. Representative collections were sent to Robert Kidston, David White, T. Rupert Jones and Henry Woodward, all of whom as pointed out Ami [**1**; **2**] and Whiteaves [**9**], united in agreeing that the fossils indicated that the strata are of Carboniferous age while Kidston and White agreed that the horizon was well up in the Carboniferous. White [**8**] in a later paper has directly presented his conclusions and has shown that Kidston and he are in essential agreement in placing the horizon of the strata at or about that of the Millstone Grit.

Ami in one of his papers [**2**, pp. 168-9], has assembled the determinations of the various palæontologists and the

following list of fossils collected from the type section of the Riversdale series along the line of the Intercolonial railway is the result. The plants were determined by Kidston, the entomostraca by T. Rupert Jones, and the crustacea by Henry Woodward.

Asterophyllites acicularis.
Sphenopteris marginata.
Neuropteris sp.
Alethopteris sp. allied to A. valida.
Cordaites principalis.
C. robbii.
Cyclopteris (Nephropteris) varia.
Calamites sp.
Cardiocarpum cornutum.

Belinurus grandævus.
Leaia tricarinata.
Leaia leidyi var. baentschiana.
Anthracomya elongata.
A. obtusa.
Spirorbis eriaia.
'A neutopteroid insect allied to Miamia bronsoni' determined by Charles Brongniart.

BIBLIOGRAPHY.

1. Ami, H. M........Geol. Surv. Can., Summary Report for 1899, pp. 201-204.

2. Ami, H. M........Proceedings and Transactions, Nova Scotian Institute of Science, vol. XI, pp. 162-178, 1903.

3. Dawson, W. J.....Geol. Surv. Can., Report on the fossil plants of the Lower Carboniferous and Millstone Grit formations of Canada, 1873.

4. Dawson, W. J.....Geol. Surv. Can., Annual Report, vol. II, p. 64 P, 1886.

5. Fletcher, Hugh....Geol. Surv. Can., Report of Progress, 1877-78, p. 18 F.

6. Fletcher, Hugh....Geol. Surv. Can., Report of Progress, 1879-80, part F.

7. Fletcher, Hugh....Geol. Surv. Can., Annual Report, vol. II, p. 50 P. 1886.

8. White, David.....Can. Record of Science, vol. III, pp. 270-280, 1910.

9. Whiteaves, J. F....Amer. Geol. vol. XXIV, pp. 210-40, 1899.

CHARACTER AND FAUNA OF THE RIVERSDALE AND UNION FORMATIONS.

(J. E. Hyde.)

The Riversdale and Union formations are each very thick. The combined thickness has been estimated to be 10,000 feet (3,050 m.) and this is probably not exaggerated. The Riversdale, which is the older, is composed of grey, red and purplish shales, with sandstone beds. It differs from the Union in the greater proportion of grey shales, the Union being almost without exception bright red in colour. There is, however, a considerable thickness of red shale in certain portions of the Riversdale.

The strata are evenly bedded and are clearly water laid. Only occasionally are there evidences of strong current action. Mud-cracked beds are not infrequent and the sandstones are composed frequently of undecomposed rocks and mineral fragments. Rarely does a thin bed of coal occur in the Riversdale.

The fauna and flora which have been described from the "Riversdale-Union" series appear to have been collected largely from the upper part of the Riversdale, but the exact localities and horizons have not been specified. Although the Union formation is almost barren, the writer has obtained the same fauna with *Leaia* and *Anthracomya* in beds almost at the top of the Union at Union station, where plant remains also occur. Both the fauna and flora are abundantly preserved in numbers of individuals if not in species, in the upper beds of the Riversdale at railroad cuts a short distance east of Riversdale station. Eastward from these cuts these remains are observed less often. Here and at every point where they have been found by the writer, the faunas are confined almost entirely to the beds of grey shale. Very rarely indeed are remains found in the red shales. The Leaia is most commonly found in beds of slaty, almost black shale. This same mode of occurrence obtains in the Point Edward formation at Sydney, believed to be an approximate equivalent of the Riversdale and Union, or of some portion of them.

ANNOTATED GUIDE.

Truro to Campbell's siding.

(J. E. Hyde.)

Miles and Kilometres.

0 m. 0 km. **Truro**— Alt. 60 ft. (18 m.). Truro is situated on the south bank of the westward flowing Salmon river which, a few miles to the westward, empties into the Bay of Minas. For 6 miles (9·6 km.) above Truro, the Salmon river flows through a tract underlain by Triassic measures consisting of red conglomerates, sandstones and shales. To the westward of Truro, similar Triassic strata fringe both sides of the Bay of Minas and continue uninterruptedly along the Cornwallis-Annapolis valley to beyond Digby 135 miles (217 km.) west of Truro. Along the north side of the Cornwallis-Annapolis valley the Triassic sediments are overlain by a thick series of flows of amygdaloidal and basaltic diabase. The Triassic measures are usually horizontal or possess low angles of dip, but locally, the measures are faulted and otherwise disturbed.

At Truro the southern boundary of the Triassic with the measures of the Riversdale-Union group lies ¼ mile (0·4 km.) south of the railway. In Victoria Park which lies just south of the station, the rocks of the Union formation are excellently shown in the walls of a stream gorge of unusual scenic beauty. The stream which is of considerable size, appears to have been deflected from its course by the Pleistocene glaciers and it has cut a short, rugged gorge into the head of which it falls in a series of cascades. The Triassic sandstones are also exposed in the park, lying on the upturned Union beds, but the contact is not clearly shown.

Leaving Truro, the Intercolonial railway proceeds in an easterly direction up the flat wide valley of Salmon river. On the north bank of the river, visible from the railway, are cut banks in red, Triassic sandstone.

Miles and Kilometres.

4·7 m. 7·6 km. **Valley Station**—Alt. 102 ft. (31 m.). Beyond Valley station, rock cuttings in the red Triassic occur along the railway and continue on the north bank of the river. After passing Valley station the river valley narrows.

6·7 m. 10·8 km. **Salmon Siding**—Salmon Siding is close to the eastern end of the Triassic basin. At this point, the contact of the Triassic with the Union formation is excellently shown on the north bank of Salmon river. The steeply dipping Union measures are truncated by a nearly horizontal plane and on them repose the flat-lying Triassic sandstones.

For a distance of about 4½ miles (7·2 km.) east from Salmon Siding, the railway follows the valley of Salmon river; beyond this point it follows up the valley of Black river, a tributary of Salmon river. From near Salmon Siding eastward to beyond Riversdale these streams are bordered by simple rock and drift terraces. The stream flows in a narrow gorge less than 100 feet (30 m.) deep below Union, which becomes shallower up stream. The rock terraces bordering this gorge are capped by 40 to 50 feet (9 to 15 m.) of drift, apparently stream laid gravels. The larger tributaries to the major streams show similar conditions.

The gravel terraces appear to belong to the closing stages of the Pleistocene. Back of Riversdale station and only 200 or 300 metres from the railroad, there is preserved on this old high-level, gravel floor, a sharply defined abandoned stream channel. It runs from the edge of Calvary river gorge westward behind the village for a distance of only a few hundred metres where it passes into a short gully which descends to Black river at Riversdale station. It is clearly the old channel of Calvary river at the time when all the streams flowed on the old high-level gravel floor, but abandoned for the present nearby outlet probably before they had cut through the gravels and into the hard rock.

Miles and Kilometres.

The channel is sharp, and indicates abandonment at a very recent period.

The relation of drift cap to rock wall can be seen fairly well in the contours of the valley walls, and both are laid bare by the cutting of Black river just opposite Riversdale station.

Apparently the rock gorge has been cut entirely subsequent to the accumulation of the gravels. No evidence has been seen of an older set of channels cut prior to the gravel stage and covered by the gravels, to be later uncovered to form in part the present gorge.

From the edge of the Triassic area at Salmon Siding, eastward almost to Union station, a distance of about 2 miles (3·2 km.), the dominantly red beds of the Union formation are shown, almost continuously, in numerous long rock cuttings, with an easterly dip of about 25°.

9 m.
14·5 km.

Union Station—Alt. 218 ft. (66·4 m.). In the rock cuttings west of Union station, the beds are on the western limb of a syncline, the highest beds of which are located just west of Union. Eastward from Union, the direction of dip is reversed, and lower and lower beds are exposed until the passage into the underlying Riversdale is reached a short distance west of Riversdale station. The contact between the Riversdale and Union is not a sharp one, and it is nor clear why Fletcher drew it at this point. It appears, however, that the boundary must be arbitrarily chosen.

12·7 m.
20·4 km.

Riversdale Station—Alt. 314 ft. (95·7 m.). West of Riversdale station, the rock cuttings are in the grey rocks of the Riversdale formation. In the rock cuttings about ½ mile (0·8 km.) east of Riversdale, fossils occur. In one cutting, the fauna, large in individuals but few in species, is found in beds of grey and black shale; at this locality, *Leaia* and *Anthrocomya* occur. In a rock cutting beyond this point, plant fragments occur abundantly in a sandy shale.

Beyond the rock cuttings west of Riversdale

Miles and Kilometres.

the valley of Black river entirely loses its deep-set character and the exposures of the Riversdale formation become more and more infrequent.

16·5 m. 26·5 km. **Campbell's Siding**—Alt. 429 ft. (103·7 m.). A short distance east of Campbell's Siding, the barren beds of the Riversdale formation are well displayed in a number of cuttings.

ANNOTATED GUIDE.

Campbell's siding to New Glasgow.

(G. A. Young.)

Eastward from Campbell's Siding the railway follows upwards along the shallow valley of Black river. The grey shales and sandstones with red zones, of the Riversdale formation are exposed in numerous rock cuttings. The strata dip at high angles to the northwest and therefore, proceeding easterly, are crossed in descendding order. Two and three-quarter miles (4·4 km.) east from Campbell's Siding, the railway crosses a low divide, (altitude 505 ft. or 153·9 m.) and enters a watershed draining to the northeast to the Gulf of St. Lawrence.

20.7 m. 33·3 km. **West River Station**—Alt. 441 ft. (134·4 m.). About 1½ miles (2·4 km.) east of West River station, the railway crosses the boundary between the Riversdale and Union formations. Few, if any, rock exposures occur along the railway.

30·1 m. 48·4 km. **Lorne Siding**—Alt. 365 ft. (111·2 m.). From near West River to beyond Lorne Siding, the railway follows close to the boundary between the Riversdale and Union formations. In this general district the sedimentary strata are associated with numerous relatively small bodies of igneous rocks whose origin and composition is unknown.

Beyond Lorne Siding the railway enters the valley of Cameron brook and at a point about 1½ miles (2·46 km.) farther enters an area of the

Miles and Kilometres.

Carboniferous Limestone series. The Riversdale strata are separated from those of the Carboniferous Limestone series by a fault, but from evidence obtained elsewhere, Fletcher was convinced that the Carboniferous Limestone series overlaid the Union-Riversdale group. The reddish shales and sandstones of the Carboniferous Limestone series are exposed in rock cuttings along the railway and in the valley of Cameron brook. The strata are much disturbed and in places are vertical. The strata of the Carboniferous Limestone series occupy a large area forming the southern boundary of the Pictou coal field. The measures are largely reddish shales and sandstone with many beds of limestone and argillaceous limestone. Logan, Dawson, Fletcher and other geologists have all agreed in calling the strata the Carboniferous Limestone series with the implication that the measures at least roughly correspond in age with the Windsor series.

35 m. 56·3 km. **Hopewell Station**—Alt. 206 ft. (62·8 m.). Before reaching Hopewell, the railway turns to the north and proceeds down a large branch of the West river of Pictou. The red strata of the Carboniferous Limestone series are exposed along the railway and on the banks of the stream, dipping in various directions, commonly at rather low angles. Approaching Eureka, the stream valley first becomes gorge-like and then broad and deep.

36·5 m 58·7 km. **Eureka Station**—Alt. 145 ft. (44·2 m.). At Eureka the railway enters the deep-set valley of the East river of Pictou. This river for 12 miles (19·3 km.) above Eureka station flows through a district underlain by strata of the Carboniferous Limestone series but towards the southeast, for a distance of about 5 miles (8·0 km.) along the railway, these measures occur only in the valley bottom and form a band nowhere more than ½ mile (0·8 km.) wide. On the south, the Limestone series is bounded by an area of the Union-Riversdale series; on the east they abut against a rough,

Miles and Kilometres.

hill country occupied by Silurian and Ordovician strata associated with large and small bodies of igneous rocks varying in character from granites to fine-grained acid and basic volcanics. Associated with the Silurian and other strata are deposits of spathic and hematitic iron ore. These deposits have been mined and at one time were smelted in furnaces at Eureka which are visible from the railway.

37·3 m.
60·0 km.
Ferrona Junction—Alt. 129 ft. (39·3 m.). The reddish strata of the Carboniferous Limestone series are exposed along the river for about 1 mile (1·6 km.) below Ferrona Junction, where for a short distance they are replaced by hard, reddish sandstones and slates thought to belong to an underlying series of Devonian age. These measures form a ridge rising to a considerable height on the east side of the river. The 'Devonian' strata are bounded by east-west faults and on the north side, the Devonian Limestone series is repeated.

After passing the narrow band of 'Devonian' the country lowers and becomes broadly rolling in character. Before reaching Stellarton, the railway leaves the Carboniferous Limestone area, crosses a mile-wide strip of Millstone Grit and enters a district occupied by Coal Measures.

40·8 m.
65·6 km.
Stellarton—Alt. 58 ft. (7·7 m.). Stellarton is one of the mining centres of the Pictou bituminous coal field. The Coal Measures in this field occupy an irregular oval-shaped area, 10½ miles (16·9 km.) long in an east and west direction and, at the widest point, about 3 miles (4·8 km.) broad. The total area of the Coal Measures is in the neighbourhood of 20 square miles (50 sq. km.). The irregular oval or lozenge outline of the area is marred towards the centre of the field by a tongue-like area of Millstone Grit projecting from the southern boundary along an anticlinal axis. Except at the western end of the field and in the neighbourhood of the above mentioned tongue-like projection of Millstone Grit, the area of the Coal Measures is bounded by a system of faults whereby the

Miles and Kilometres.

Coal Measures along the southern boundary are brought into contact with strata of the Limestone series, while along the eastern and northeastern boundary they are brought into contact with the Millstone Grit, and along the northwestern boundary into contact with the New Glasgow Conglomerate supposed by Fletcher to be of Permian age. The fault system is a complex one and comparatively little has been recorded of the magnitude and nature of the individual faults. In general there appears to be a set of major faults striking in an east and west direction; another set in a northeasterly direction and a third set in a northwesterly direction. The Coal Measures are also traversed by faults and one of these striking in a northwesterly direction, dipping to the northeast, and causing a downthrow of the strata on the southwest side of approximately 2,600 ft. (790 m.), divides the field into two main districts, respectively the western and eastern districts. In the western district, the strata dip in general to the northeast at angles varying from 15° to 50°. In the larger, eastern district, the strata in the eastern part are traversed by a north-south syncline while in the western part the main feature is a northeasterly pitching anticline. The major structural features of the two areas are complicated by the presence of minor undulations extending in an east-west as well as other directions, and of many faults of varying relative importance.

In the eastern district, which includes the district immediately around Stellarton, the coal seams occur in two sets, an upper and a lower, separated by about 1,600 feet (485 m.) of barren rock, mostly dark shale. The upper set of coal seams is exposed in the eastern part of the area, and the lower set in the western part in the neighbourhood of Stellarton. In the upper set there are five main seams of coal varying in thickness from 3 feet to 8 feet (0·9 m. to 2·4 m.). In the lower set there are six main coal seams. One seam, known

Miles and Kilometres.

as the Main seam, varies in thickness as traced along the outcrop or in depth, from less than 7 feet (2·1 m.) to 45 feet (13·7 m.). Another seam ranges in thickness from 20 feet (6 m.) to 33·5 feet (10 m.). A third seam, the lowest, varies in thickness from 11 feet to 19 feet (3·3 m. to 5·8 m.).

In the western of the two main areas, there are four main coal seams supposed to be the equivalents of seams of the lower set occurring in the Stellarton district. As in the eastern district the individual seams vary widely in thickness from place to place. The largest seam varies in this respect from less than 4 feet to 18 feet (1·2 m. to 5·4 m.).

From Stellarton the railway continues for about 1½ miles (2·4 km.) along the west side of the East river of Pictou, then crosses the river and enters the town of New Glasgow. A very short distance beyond the station, the railway crosses the course of an east-west fault limiting the area of the Coal Measures in that direction.

42·9 m. 69 km. **New Glasgow**—Alt. 29 ft. (5·8 m.).

THE NEW GLASGOW CONGLOMERATE.*

(G. A. Young.)

INTRODUCTION.

Along the banks of the East river, in the vicinity of New Glasgow, are exposures of a red, coarse conglomerate which has received the name, New Glasgow Conglomerate. This formation is the basal member of a very thick group of strata which in a comparatively undisturbed condition, floor the country north and west of New Glasgow, outcropping along the Nova Scotian and New Brunswick shores of Northumberland strait for a distance of about 80 miles (130 km.), and underlying the whole of Prince Edward Island. What have been described as equivalent

* See Map,—New Glasgow.

measures also occur in the western part of the Joggins section along the Bay of Fundy coast. The distribution of this group of strata is confined, so far as known, to the general region lying north of the Cobequid Hills which stretch easterly from the Bay of Fundy to not far from New Glsagow, a distance of about 100 miles (160 km.). In the portion of Nova Scotia north of the Cobequid Hills and the adjacent portion of New Brunswick, and in Prince Edward Island, this thick group of strata of which the New Glasgow Conglomerate in places forms the base, occurs in four distinct basins or areas. One, the Prince Edward Island area, occupies the whole of that island and is separated by the waters of Northumberland strait from a second which lies on the mainland fronting Prince Edward Island. The second area stretches westerly to the head of the Bay of Fundy, lies partly in New Brunswick, partly in Nova Scotia. It is separated from the two remaining areas by an anticlinal axis of folding running eastward from the head of the Bay of Fundy to Northumberland strait and along which are exposed Carboniferous strata of the age of the Productive Coal Measures and older. The third area fronts on the Bay of Fundy coast, forms the western portion of the famous Joggins section, and extends inland along the north flank of the Cobequid Hills. It is separated from the fourth area by axes of folding along which are exposed older Carboniferous rocks. The fourth area may be named the New Glasgow area. It stretches from New Glasgow westward along the north flank of the Cobequids and northward from the foot of the hills to Northumberland strait.

This widely extended and thick group of strata of which in certain districts, the New Glasgow Conglomerate forms the natural base, appears everywhere to form a conformable series and in places, even appears conformable with the Productive Coal Measures. The strata are largely sandstones and because, in certain districts, varieties of a red colour predominate, the earliest geological observers assigned the group in general, to the Triassic. As geological investigations progressed, the term Triassic was applied only to the supposedly higher members of the group as displayed in Prince Edward Island. Later the application of the term Triassic was restricted to a small portion of the highest beds on Prince Edward Island in which had been found reptilian remains of a supposedly

Triassic genus. Still later, it was determined that the reptilian remains had been misidentified and that they represented a lower Permian genus; consequently the highest beds on Prince Edward Island are definitely considered to be of Permian age.

During the flux of time as opinions changed regarding the age of the highest members of this great group of strata, various terms were applied to the lower divisions by Sir W. J. Dawson and other observers, These terms were such as Newer Coal formation [**1**], Upper Coal formation [**2**], Permo-Carboniferous [**4**], Permian, etc. In all cases the different terms were used with the definitely stated or plainly implied meaning that the group of strata represented a thick series laid down uninterruptedly from late Carboniferous on into Permian time. In certain districts as for instance where the strata are exposed along the Joggins shore, there is no appearance in the exposed sections of an unconformity between the Carboniferous Coal Measures and the overlying Permo-Carboniferous group. In other districts, as in the neighbourhood of New Glasgow, the evidence implies the existence of a profound stratigraphical break above what is customarily considered to be the horizon of the Productive Coal Measures but below the summit of the Carboniferous. Presumably, sedimentation ceased over the greater part if not over the whole region in later Carboniferous time, and in places at least, the strata were folded, faulted and eroded. In other places the strata were scarcely deformed at all, perhaps but little eroded and, it is possible that in some local areas the processes of sedimentation may have operated continuously. At a later date but still before the close of Carboniferous time, the processes of sedimentation were renewed and continued in force during the closing epochs of Carboniferous and the opening period of Permian time.

The conclusion that the strata of the above mentioned four areas are all portions of one great, unbroken group, rests on evidence collected by Dawson and afterwards substantiated by the detailed field studies prosecuted by Fletcher. There does not seem to be any reasonable grounds for doubting the truth of this general conclusion. It is, however, as yet uncertain how high the strata range in the four main areas though it has generally been thought

that the highest strata are present only on Prince Edward Island. In the New Glasgow area the total thickness of the strata is very great. In the case of one section, a detailed estimate by Fletcher [**8**, p. 114] gives a thickness of above 8,000 feet (2,440 m.) chiefly sandstones, and shales, overlying a basal series of conglomerates, etc., of undetermined thickness but presumably not less than 1,000 feet (300 m.). In the case of a second section [**8**, p. 117] measured a few miles to the west of the first, the thickness including the conglomerate strata at the base, amounts to slightly over 5,000 feet (1,520 m.). The difference in the total estimated thickness of the two adjoining sections is in part accounted for by the presence of a fault in the case of the section with the smaller total. However, having regard to the character of the strata, it is reasonable to suppose that the total thickness may vary rapidly from place to place. In view of what has been stated it may be concluded that the total thickness of the whole group is not less than 10,000 feet (3,000 m.).

The age of the group in general, depends upon the finding of reptilian remains in what are supposed to be the highest strata of the group on Prince Edward Island; and on the palæobotanical studies of Dawson. The facts of the case in connection with the reptilian remains have been summed up by Lambe [**10**] as follows:—The fossil remains found, consist of a "portion of the head of the Rhynchocephalian reptile (which was) described in 1854 by Leidy as the mandibular ramus of a Triassic dinosaur under the name *Bathygnathus borealis*. In 1876,. . . . ., Sir Richard Owen drew attention to the fact that the specimen appertained in reality to the upper jaw and referred it to the Theriodontia. Later in 1905, v. Huene and Case independently recognized its true position in the Pelycosauria but its exact generic affinities are still in doubt. . . . . The Pelycosauria are typical of the Permian."

The following tabulation of the plants recovered from the Permo-Carboniferous is based on one prepared by Dawson [**4**] with the addition of a few species which Dawson believed came from Triassic measures on Prince Edward Island [**3**].

	Nova Scotia.		Prince Edward Island.	
	Lower Part.	Upper Part.	Lower Part.	Upper. Part.
Dadoxylon (Araucaroxylon) edvardianum	....	....	....	x
Cycadoidea (Mautellia) abequidensis	....	....	....	x
Dadoxylon materiarium	x	x	x	....
Walchia (Araucarites) gracilis	....	x	x	....
W. robusta	....	....	x	....
Sigillaria scutellata	x	....	....	....
Calamites suckovii	x	x	x	....
C. cistii	x	x	x	....
C. gigas	....	....	x	....
Calamodendron approximatum	x	....	....	....
Annularia sphenophylloides	x	x	....	....
A. longifolia	x	x	....	....
Sphenophyllum emarginatum	x	....	....	....
S. longifolium	x	....	....	....
Cyclopteris heterophylla	x	....	....	....
C. fimbriata	x	....	....	....
Neuropteris flexuosa	x	x	....	....
N. cordata	x	x	....	....
N. heterophylla	x	....	....	....
N. rarinervis	x	x	x	....
N. auriculata	x	x	....	....
Odontopteris schlotheimii	x	....	....	....
Sphenopteris latior	x	....	....	....
Alethopteris nervosa	x	x	x	....
A. serlii	x			....
A. acuta	x	....	....	....
Pecopteris arborescens	x	x	x	....
P. abbreviata	x	....	....	....
P. unita	x	....	....	....
P. rigida	..	x	x	....
P. oreopteroides	x	x	x	....
Beinertia goepperti	x	....	....	....
Palaeopteris acadica	x	....	....	....
Cordaites simplex	x	x	x	....
Lepidodendron pictoense	x	x	....	....
L. undulatum	x	....	....	....
Lepidophloios parvus	x	....	....	....
Trigonocarpum noeggerathii	x	....	....	....
Rhabdocarpus insignis	x	....	....	....
Antholithes squamosus	x	....	....	....

Though by all geologists it has been conceded that the New Glasgow Conglomerate at New Glasgow, is the base of a continuous series of sediments whose upper portion is of Permian age, yet there are two views advocated regarding the age of the New Glasgow Conglomerate itself. By Dawson and Hartley it has been contended that the conglomerate is of Millstone Grit or early Productive Coal Measures age; this view was accepted by Logan. On the other hand, Poole and Fletcher have argued that the conglomerate is of post-Productive Coal Measures age. Dawson [**6**] based his view on two chief lines of evidence.

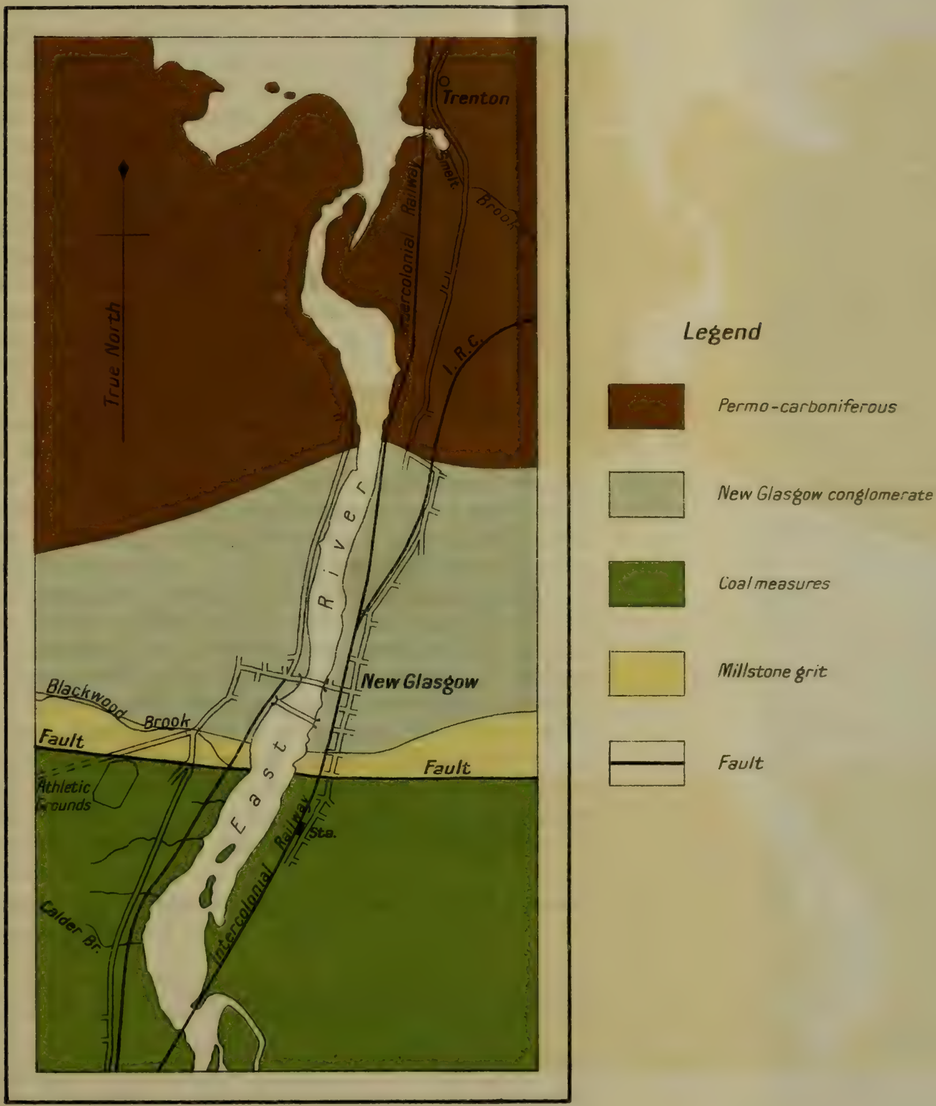
(Firstly) A few miles west of New Glasgow there is some appearance of an anticlinal fold in the conglomerate suggesting that the strata are developed along a deformed anticline and thus, countenance, the view that the strata may underlie the Coal Measures lying not far east. (Secondly) Dawson states that the fossils from the strata immediately overlying the conglomerate, are similar to those occurring in the Productive Coal Measures. Unfortunately, so far as known, no list of these fossils plant and fish remains have ever been published.

Pool [**12**] and Fletcher [**7** and **8**], contend that the New Glasgow Conglomerate is of post-Productive Coal Measures age because of two main reasons:—(firstly) the conglomerate uncomformably overlies the Millstone Grit and (secondly) no strata similar to the New Glasgow Conglomerate have been found beneath the Coal Measures in other parts of the Pictou coal field or elsewhere in Nova Scotia. Other lines of evidence support the general argument of Poole and Fletcher and, in the absence of any detailed statement of the palæontological evidence, appear to be quite conclusive.

DETAILED DESCRIPTION.

Logan has described the New Glasgow Conglomerate in the following terms [**11**].

"At the bridge of New Glasgow is exposed a series of conglomerates, which, in general colour, are between a brick-red and chocolate or indian-red, and whose enclosed masses, varying from the smallest pebbles to boulders of two feet in diameter, are for the most part, unmistakably derived from the red and greenish-grey sandstones, red shales and impure nodular limestones of the rock last described (Millstone Grit), some of them containing the



Geological Survey, Canada.

New Glasgow

Feet

500 0 1000 2000 3000

Metres

0 500 1000

same vegetable organic remains. With these pebbles and boulders are associated a few from the rocks still lower down (pre-Millstone Grit). The whole are inclosed in a matrix of the same mineral character, constituting an argillo-arenaceous cement, which is also calcareous, and in the interstices of the boulders and pebbles is often observed a network of white calc-spar aiding to keep them together. There are interstratified in the rock, bands, from a few inches to several feet in thickness, of fine red sandstone and red shale, which serve to give assurance of the dip....... From a point a short distance above the bridge, to one much farther below, these conglomerates have a breadth of very nearly a mile, with a dip, which on the average is N. 3°-13° W., with a slope gradually diminishing from 50° in the lower to about 30° in the upper part, and giving a total thickness of about 1,600 feet (490 m.)".

Along the bank of East river, the strata conformably overlying the New Glasgow Conglomerate are imperfectly exposed. On the west shore beyond a short concealed interval, occur fine-grained, pale yellow sandstones dipping northward at an angle of about 10°. On the east bank a bed of limestone outcrops that apparently occupies a place in the section intermediate between the conglomerates and the above mentioned pale coloured sandstones. About 3 miles (4·8 km.) to the east a similar limestone directly overlies the conglomerate and is succeeded by shales with a thin seam of coal. On the east shores of the river commencing at a place about 1,500 feet (450 m.) north of the conglomerate, where the shore bends to the east, and then northward to the mouth of Smelt brook, are exposures of sandstones and shales.

A generalized description of the overlying series has been given by Dawson [**5**] and is as follows:—

'1. ....the conglomerate is succeeded in ascending order by a grey concretionary limestone 20 feet (6 m.) thick, associated with sandstone and shale, and containing in some layers great number of the Spirorbis which I have described as *S. arietinus*.

2. Above this is a series of black shales and underclays with grey sandstones and some reddish and purple shales, and thin seams of bituminous shale and coal. These beds contain Stigmariae, Lepidodendra, Entomostracans, and fish remains; the fossils and the mineral character of the beds alike corresponding with those seen in the upper part of the Coal Measures south of the conglomerate. The thickness of these beds is about 400 feet (120 m.).

3. This series is succeeded by a thick grey sandstone holding Calamites, Calamodendron, trunks with aerial roots, etc., 30 to 50 feet (9 to 15 m.) thick. This appears at the mouth of Smelt Brook, and in several quarries to the eastward of that place.

4. Above this is a second series of dark shales and underclays, and bituminous shales associated with grey sandstones, and containing fossils similar to those of the

series below. It especially abounds in fish scales and Cythere; and several of the fishes are specifically identical with those of the upper part of the Middle Coal Measures, as seen in the southern trough south of New Glasgow. These beds are about 200 feet (60 m.) thick.

5. The beds up to this point may be considered the equivalents of the Middle Coal Measures, or of the upper part of them, and are now succeeded in ascending order by thick grey and reddish sandstones, and reddish and grey shales............These may be regarded as belonging to the Upper Coal formation........................'

The New Glasgow Conglomerate in the form of a band about ½ mile (0·8 km.) wide, extends eastward from New Glasgow to the shores and islands of Merigomish harbour, distant about 6 miles (9·6 km.). The measures in this band dip uniformly northward at angles ranging between 45° and 60° along the southern edge of the band, and 15° to 30° along the northern margin. In the eastward extension of the formation sandstones become relatively more abundant and, on the islands in Merigomish harbour, sandstones predominate over the conglomerates. Westward of New Glasgow, the conglomerate outcrops over a band-like, area for a few miles, but beyond this, owing to folding, faulting, etc., the band-like character is lost.

East of New Glasgow, the conglomerate directly overlies measures that by all geologists have been ascribed to the Millstone Grit. West of New Glasgow, for a distance of about 1 mile (1·6 km.), the conglomerate rests on strata generally ascribed to the Millstone Grit, but beyond this point, the New Glasgow Conglomerate is separated by faults, from the adjoining strata on the south, or where not bounded by faults, rests on strata considered to be Devonian or older. Nowhere in the general district, does the New Glasgow Conglomerate come in direct contact with the Coal Measures.

East of New Glasgow, the New Glasgow Conglomerate and the underlying Millstone Grit dip, as stated by Logan, [**11**] "in such a way as, without other evidence, to induce the supposition that the one series overlies the other conformably". To the eastward, the Millstone Grit strata are displayed over a wide district but approaching New Glasgow, these measures because of the presence of an east-west fault are limited to a very narrow zone and are followed to the south, beyond the fault, by the Coal Measures.

In the partial geological section displayed in the vicinity of New Glasgow, along the west banks of East river, a few exposures of the New Glasgow Conglomerate dipping northward at an angle of 60°, occur above the highway bridge. Along the river side, above these out-

crops there is a concealed interval beneath which lies the lower portion of the New Glasgow Conglomerate, and the narrow strip of underlying Millstone Grit. The first exposures beyond, about opposite the New Glasgow railway station, belong to the Coal Measures. The strata there dip to the east at an angle of 45° and consist of a partly reddish, partly greyish grit containing angular fragments of quartz. The grit overlies a very fine-grained, pale-coloured sandstone. A few yards farther upstream the strata dip to the south at an angle of 55° and consist of fine-grained, pale grey sandstone streaked with thin beds or lenses of nearly black sandstone. Possibly the strata of these two exposures are separated by a fault.

A short distance to the south, at the mouth of a small brook, occur dark, nearly black, thinly bedded shales with interbeds of fine sandstone. The strata dip to the northeast at an angle of 60°. They are underlain by beds of rather hard, light grey, fine-grained sandstone which in the bank, in a space of 10 feet (3 m.) are seen to be folded along the strike through an angle of 60°. Plant remains occur in these beds.

About 40 yards (35 m.) to the south, the strata dip to the northeast at an angle of 30°. They consist of dark shales with thick beds of fine-grained, light grey sandstones in some of which plant and fish remains are abundant. Beyond this the shales become slaty, and at one place, for a space of a few feet, are nearly horizontal. Beyond this they resume their normal dip to the northeast.

Farther south, near the mouth of a small brook, similar strata outcrop, dipping to the east at angles of about 40°. Farther south at Calder brook and beyond are outcrops of the dark shales and light coloured sandstones dipping towards the east. In general the measures as displayed along this portion of the river, dip to the east but they are crumpled and doubtless are traversed by minor faults. That these beds belong to the Coal Measures does not appear to have ever been doubted by any geologist who has studied the district.

As already stated the New Glasgow Conglomerate and the underlying Millstone Grit as displayed to the east of New Glasgow dip and strike as though they were portions of one conformable series. To the west of East river it has been stated however, by various authorities that the New Glasgow Conglomerate unconformably overlies the

Millstone Grit. Hartley [**9**)], Fletcher [**8** p. 110], and Poole [**13**] have stated that this unconformity is visible along the course of Blackwood brook at points just to the west of the crossing of the highway paralleling the west bank of East river. Hartley and Poole unequivocally place the underlying strata in the Millstone Grit, but Fletcher states that possibly the beds belong to the Carboniferous Limestone series.

From the crossing of Blackwood brook by the highway, a road leads westward along the south side of Blackwood brook. From this road, ledges of the New Glasgow Conglomerate may be seen outcroping along the north bank of Blackwood brook. The coarse red conglomerate presents very few indications of bedding but appears to dip northward at an angle of about 40°. The conglomerate is exposed at intervals along the low bluff extending westward along the north side of the brook.

On the road leading westward, one or two imperfectly exposed outcrops of the underlying series occur, but they are better exposed farther to the west in the gully of a small waterway crossing the road near the northwestern corner of the Athletic Grounds. In this gully occur fine-grained sandstones, red in colour but irregularly streaked with grey. Towards the mouth of the small waterway, where it joins Blackwood brook, the sandstones dip to the northeast at an angle of 70°; a short distance up Blackwood brook, in the bed of the stream, the red sandstones are vertical; a short distance farther up stream, in the low bluff on the north bank, the sandstones are in direct contact with the New Glasgow Conglomerate and both sets of beds dip at very high angles to the northeast without any evidence of angular unconformity.

Thus even in the one place specifically cited by Hartley, Poole and Fletcher, there is no conclusive evidence of the existence of angular unconformity between the New Glasgow Conglomerate and the underlying strata presumed to be of Millstone Grit age. Where the exact contact of the two formations is visible, no angular unconformity is visible. The variations in the direction and value of the angle of dip of the two formations, are no greater in this neighbourhood than may be observed in the case of the conformable series of beds composing the Coal Measures. The conclusion is that west of East river, the New Glasgow Conglomerate overlies the Millstone Grit without angular

unconformity as it does in the cases described by Logan east of East river. In view of the evidence, the belief held by Dawson, that the New Glasgow Conglomerate is only a phase of the Millstone Grit does not seem impossible and might be considered as established if the palæontological evidence of the age of the beds overlying the New Glasgow Conglomerate had been fully stated and had then been found to bear out Dawson's contentions. But in spite of the seeming absence of any angular unconformity, that a disconformity does exist between the New Glasgow Conglomerate and the Millstone Grit seems to have been established by Logan, and, later, by Fletcher. How great an interval of time is represented by this disconformity is not altogether apparent and therefore the age of the New Glasgow Conglomerate can hardly be considered to be as yet established.

BIBLIOGRAPHY.

1. Dawson, J. W. Proceedings Geol. Soc. Lon., Vol. IV, pp. 272-281, 1843-45.

2. Dawson, J. W. Quart. Journ Geol. Soc. Lon., Vol X, pp. 42-47, 1854.

3. Dawson. J. W. Report on the geological structure and mineral resources of Prince Edward Island, 1871.

4. Dawson, J. W. Quart. Journ. Geol. Soc. Lon., Vol. XXX, pp. 209-218, 1874.

5. Dawson, J. W. Acadian Geology, Fourth Edition, Supplement to Second Edition, p. 35.

6. Dawson, J. W. Acadian Geology, Fourth Edition, pp. 322, et seq.

7. Fletcher, Hugh Geol. Surv. Can., Vol. II, 1886, part P.

8. Fletcher, Hugh Geol. Surv. Can., Vol. V., 1890-91, part P.

9. Hartley, E. Geol. Surv. Can., Report of Progress 1866-69, p. 66.

10. Lambe, L. M. Proceedings and Transactions, Roy. Soc. Can., Vol. V, sec. 4, p. 6, 1911.

11. Logan, W. E. Geol. Surv. Can., Report of Progress 1866-69, p. 13.

12. Poole, H.S . — Proceedings and Transactions, Nova Scotian Inst. Sci., Vol. VIII, pp. 228-343, 1890-94

13. Poole, H. S. — Geol. Surv. Can., Vol. XIV, 1905, part M, p. 11.

ANNOTATED GUIDE

NEW GLASGOW TO SYDNEY.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

New Glasgow—Alt. 29 ft. (8·8 m.). Leaving New Glasgow the Intercolonial railway crosses in a northward direction, the band of New Glasgow Conglomerate and ent[illegible] the [illegible] so-called Permian strata that [illegible] wes[illegible] for about 75 miles (120 km.) along the shores of Northumberland strait. At a distance of about 7 miles (11·2 km.) from New Glasgow, the railway recrosses the band-like area of New Glasgow Conglomerate and enters the eastern extension of the Carboniferous area containing the Pictou coal field.

The Carboniferous strata of the area traversed by the railway belong almost entirely to the Millstone Grit. The measures are mainly reddish and greyish shales and sandstones with occasional beds of limestone and are folded and faulted. The Carboniferous area is low and rolling, and forms a narrow strip of country, 3 to 4 miles (5 to 6·5 km.) wide, extending from the sea and bounded on the south by a high rugged area having a general altitude of about 1,000 feet (300 m.). This upland rises abruptly from the Carboniferous area and is underlain by Silurian and older strata (Ordovician?) with which are associated bodies of intrusive and extrusive igneous rocks. The strata lie in a highly disturbed condition and, especially in the case of the pre-Silurian measures, are in many places schistose or otherwise metamorphosed.

Miles and Kilometres.

22·3 m. 35·9 km. **Avondale Station**—Alt. 151 ft. (46 m.). At Avondale, the railway enters the upland region of Silurian and older strata and follows a series of low valleys that cut completely through it. The elevated district extends in an eastward direction for about 25 miles (40 km.) and ends in a promontory on the sea coast. In the opposite direction, the highland joins the central upland area that extends, though with some interruptions, in a southwesterly direction for about 200 miles (320 km.) and forms the axis of the peninsula of Nova Scotia.

32 m. 51·5 km. **James River Station**—Alt. 255 ft. (77·7 m.). Shortly before reaching James River station, the railway leaves the upland area of disturbed Silurian and older measures and enters a low rolling area occupied by disturbed Carboniferous strata presumably belonging to the Windsor series. The low-lying Carboniferous area extends eastward to the sea. It is bounded on the north and east by the highlands of Silurian and older strata, while on the south it is limited by an upland area of strata belonging to the Riversdale-Union group.

41·5 m. 66·8 km. **Antigonish**—Alt. 20 ft. (6·1 m.). Beyond Antigonish the railway passes along the seaward border of the Carboniferous area. For a number of miles the low-lying country is underlain by measures supposed to belong to the Windsor series, but, farther east, the railway enters a bordering area of older Carboniferous strata.

70·2 m. 113·0 km. **Harbour au Bouche Station**—Alt. 271 ft. (82·6 m.). One mile (1·6 km.) beyond Harbour au Bouche, the railway enters a wide area of folded and faulted measures belonging to the Riversdale-Union group. These measures form the western shore of Cabot strait, distant a few miles to the east, and have been traced almost uninterruptedly as far as the neighbourhood of Windsor 150 miles (240 km.) to the southwest.

Miles and Kilometres.

80·2 m. 129·1 km. **Mulgrave Station**—Mulgrave station is situated on the western shore of Canso strait which separates the island of Cape Breton from the mainland. At this point the straits are about three-quarters of a mile (1·2 km.) wide. A ferry transports the trains across the straits to Point Tupper on Cape Breton island.

80·9 m. 130·1 km. **Point Tupper Station**—The island of Cape Breton has an area of about 3,600 square miles (9,360 sq. km.). About one half of the area of the island is underlain by Carboniferous measures while the remainder is occupied by Pre-Cambrian strata with minor areas of Riversdale-Union and Cambrian beds. The Pre-Cambrian rocks in general form upland areas rising to heights of from 500 feet to 1,500 feet (150 m. to 450 m.) above the sea. The Carboniferous strata occupy low-lying areas surrounding and penetrating the detached Pre-Cambrian uplands. The railway from Point Tupper to Sydney, follows in the main, a series of valleys in the Carboniferous areas but in places crosses low-lying areas of Cambrian and Pre-Cambrian rocks.

127·1 m. 204·5 km. **Grand Narrows Station**—Just before reaching Grand Narrows station the railway crosses Barra strait which connects Bras d'Or and Little Bras d'Or lakes. These two salt-water lakes are directly connected with the sea and, extending inland in a southeasterly direction, almost completely divide Cape Breton into two islands.

172·0 m. 276·8 km. **Sydney.**

SYDNEY COAL FIELD.*

INTRODUCTION.

(G. A. Young.)

The name, Sydney coal field, is applied to the area of Carboniferous strata fringing the northeastern coast of Cape Breton for above 30 miles (48 km.) from Cape

*See Map—Sydney Coal Field.

Dauphin on the west, to Mira bay on the east. The area occupied by these measures amounts to about 300 square miles (780 sq. km.) of which total about 50 square miles (130 sq. km.) is underlain by the Productive Coal Measures. In addition to the land area of the Productive Coal Measures, there is, by reason of the low seaward dip of the strata, a very considerable submarine area from which coal may be won.

The Sydney Carboniferous basin is notable for the splendid sections exposed along the coast and for the great thickness of the strata, which, in the vicinity of Sydney harbour, reaches approximately 12,600 feet (3,840 m.). The section is characterized by the apparent absence of pronounced stratigraphical breaks. In general, the geological structure is simple in form, the angles of dip low, and although a few prominent faults occur, the greater part of the field is free from them.

By reason of a series of low folds and certain indentations of the coast, the coal field is naturally divisible into six coal basins or districts. All of these with but one exception, contain, besides a number of minor seams, 5 to 8 seams of coal varying from 2 feet (0·6 m.) to 13 feet (3·9 m.) in thickness. The total thickness of coal in seams that may be workable varies in the five main basins from 23 feet (7 m.) up to 47 feet (14·3 m.). The coal is of a bituminous variety and in 1911 the total production amounted to above 4,900,000 tons. The individual seams are traceable for miles along the strike, in fact many of them are believed to extend throughout the whole length of the field. The individual seams vary somewhat in quality along the strike, change in thickness in a rather remarkable manner, and in some cases what is one seam in one locality becomes two in another because of the greatly increased thickness of an elsewhere relatively insignificant parting.

The fund of general geological information concerning the Sydney Carboniferous area is contained, almost entirely, in early reports by Charles Robb, and Hugh Fletcher, published by the Geological Survey in the '70s. and in a series of maps by Fletcher which are, in part, revisions of earlier editions. Important contributions to the geology of the district were made by Richard Brown at one time manager of a coal company operating in the field. The varied and striking palæobotanical material described by

Bunbury and Dawson was mainly collected by Brown, chiefly from the North Sydney area and in no small part from one shale bed overlying the Main seam. From this single horizon, it is stated by Brown, that over 90 plant species were obtained.

The Carboniferous strata of the district have been grouped and mapped under four divisions of which the highest, the Productive Coal Measures, embraces the youngest consolidated rocks in the region. The different divisions, in a general way, are displayed over long areas trending east and west, parallel to the coast line—the highest divisions bordering the coast, the lower divisions developed inland towards the south and resting on Cambrian and Pre-Cambrian strata. The Pre-Cambrian comprises plutonic, volcanic, and highly metamorphosed sedimentary strata; the Cambrian is mainly of sediments which are in part fossiliferous.

The Carboniferous area, bordered on the north and east by the Atlantic, is essentially a low, rolling country seldom rising higher than 350 feet (105 m.) above the sea while the Pre-Cambrian and Cambrian areas situated to the south and west are more broken and in part consist of long ranges of high hills rising abruptly from partly encircling Carboniferous lowlands, to heights of from 500 to 1,000 feet (150 to 300 m.) above sea level. The coast line is broken by bays and channels of the sea running inland in a southwesterly direction. One of the larger of these indentations is that of Sydney harbour situated towards the centre of the basin and forking towards its head into two arms each of which is continued inland by a long valley. Farther west, cutting through the Carboniferous lowland, are two long channels leading southwestward into the salt water Bras d'Or Lake which occupies so much of the central part of Cape Breton island.

The general southwesterly trend of the depressions occupied by the sea, of the courses of the axes of folds in the Carboniferous, and of the high ranges of Pre-Cambrian and Cambrian strata, is a marked feature. The presence of the Carboniferous over the lowlands that border and penetrate the high hills of Pre-Cambrian and Cambrian rocks, the overlapping of various divisions of the Carboniferous on these ancient strata, the relatively undisturbed attitude and the comparatively coarse nature of the bulk of the thick series of Carboniferous measures

are signs which point to the conclusion that the topography of the present day in some measure reflects that of early Carboniferous time.

The nearness to the old shore of the portion of the Carboniferous basin still preserved doubtless, in part at least, explains the great volume and general characters of the sediments. Possibly a considerable proportion of the supposed thickness may be explained as due to dip of deposition.

The general similarity of the Carboniferous measures as displayed in Cape Breton, to those on the mainland of Nova Scotia and over New Brunswick, along the southern and western edge of the Gulf of St. Lawrence; the resemblance of these beds to those developed in Newfoundland on the east side of the St. Lawrence gulf; and the occurrence of Carboniferous strata on the Magdalen islands situated towards the centre of the hydrographic basin, have lead various observers to believe that the Sydney Carboniferous area represents a remnant of the southern border of a once continuous basin of Carboniferous strata that may have occupied the greater part of the area of the Gulf of St. Lawrence.

The Carboniferous section of the Sydney field is customarily divided into the following groups, tabulated in descending order with approximate thickness as developed in the vicinity of Sydney harbour.

Productive Coal Measures	1,970 feet	(600·5 m.)
Millstone Grit	3,625 feet	(1,105·0 m.)
Limestone series	4,500 feet	(1,371·6 m.)
Conglomerate series	2,525 feet	(769·6 m.)
Total	12,620 ft.	(3,846·7 m.)

The *Conglomerate series* consists essentially of red conglomerates, sandstones and shales. The conglomerates predominate and their waterworn pebbles and boulders are often of large size. Calcareous material in places forms the matrix of the conglomerates and occasional impure beds of limestone occur.

The *Limestone series* includes a great thickness of sandstone and shales, red and grey or green in colour, also conglomerate horizons, and many beds of limestone that frequently are fossiliferous. Only one bed of gypsum

is known to occur in this series in the neighbourhood of Sydney harbour though a few miles to the west and in other areas of the Carboniferous, gypsum forms an important member of the series.

The *Millstone Grit* is largely composed of coarse and fine, grey or green sandstones in part conglomeratic especially towards the base of the series, and shales usually dark in colour. In the eastern part of the field shales are relatively more abundant, are more largely red, and at least one important coal seam is present, whereas, to the west the shales are generally dark, are less abundant, the conglomeratic phases of the sandstone are more prominent and coal seams are absent or relatively unimportant.

The *Productive Coal Measures* are largely shales, commonly dark coloured but also in part red or green, and light coloured sandstones. Thin persistent beds of dark limestone form a characteristic feature of the lower portion of the division. In various measured sections, there is, on an average, 24 coal seams with a total average thickness of 46 feet (14 m.) of coal.

The thickness of the three lower divisions varies from place to place. At the eastern end of the field, on the shores of Mira bay, the Millstone Grit has an estimated thickness of about 5,700 feet (1,740 m.); on Sydney harbour, the measured thickness is 3,625 feet (1,105 m.); while farther west, the thickness decreases to about 2,000 feet (610 m.). The Limestone series shows a more marked variation in thickness, ranging from 4,000 feet (1,220 m.) or more at the foot of Sydney harbour to less than 900 feet (275 m.) on the east side of George river only 4 miles (6·4 km.) to the west. The Conglomerate series exhibits a still wider range of thickness, since in places it is altogether wanting.

Of the great volume of Carboniferous strata, by far the greater part is apparently of continental origin and practically only in the case of the Limestone series with its fossiliferous limestones and shales, is there positive evidence of normal marine origin of any of the strata. The evidence found in the Productive Coal Measures of the former existence *in situ* of forest growth; the abundant plant remains found in the Millstone Grit and their occurrence in a fragmentary state in the Conglomerate series; the character of, and the channeling phenomena, etc. exhibited by the sandstone beds that form so large a part

of the whole section; and other lines of evidence, all indicate that throughout the greater part of the period of deposition, the Sydney area was above sea level though presumably forming part of a low lying coast.

On palæobotanical, stratigraphical and lithological grounds, the Productive Coal Measures have been correlated with the divisions of the same name in the other coal basins of Nova Scotia. The Millstone Grit presents the same general features in all the basins. These two representatives of the Pennsylvanian, as well as portions of the underlying series, in many ways present a remarkable parallelism with the equivalent horizons of the famous Joggins section 200 miles (320 km.) away. Owing to the encroachment of the sea, the highest beds of the Productive Coal Measures, if ever present, are no longer visible. In other Nova Scotia coal fields, this series is generally succeeded by strata classified as Upper or Newer Coal formation (Dawson) or Permo-Carboniferous or Permian (Fletcher).

The Limestone series from which, at Sydney, a comparatively meagre fauna has been obtained, has generally been regarded as in some measure the equivalent of the Windsor series and therefore of Mississippian age. The Conglomerate series has not been with any certainty correlated with horizons in the coal basins on the mainland of the province, and, indeed, there are good reasons for believing that under this name, in different districts, entirely different formations have been grouped.

By some the whole Carboniferous section at Sydney has been described as a strictly conformable series but, Fletcher, who devoted the work of a lifetime largely to the Carboniferous of Nova Scotia, always held that a break existed between the Millstone Grit and the Limestone series but agreed on the other hand, that the divisions between the Millstone Grit and the Productive Coal Measures, and between the Limestone series and the Conglomerate series, were in the main, arbitrary ones. The same authority for a while, was inclined to maintain that the measures of the two lower divisions were,in different fields, in part at least contemporaneous, but at a later date, Fletcher, as he extended his work over the various areas of Carboniferous in Nova Scotia, abandoned this idea and came to regard the Conglomerate series as a distinct

group, the lowest of the Carboniferous horizons or, possibly, belonging to the Devonian in part or in whole.

As a result of recent investigations in the Sydney field, Hyde (see later pages) divides the original Limestone series in two and links the upper subdivision with the Millstone Grit, and the lower with the typical Windsor series.

The geological structure of the Sydney Carboniferous area is of a comparatively simple type. Over large areas the strata dip with low angles ranging in value from 5° to 20°, and the greater part of the district is free from faulting. The whole basin is divisible into four subordinate synclinal basins whose axes in the west, strike N.E. and S.W. but towards the east have a more nearly E.-W. trend. These folds with their limbs in most cases dipping at low angles, apparently all pitch seaward so that along the coast, the highest Carboniferous strata, the Productive Coal Measures, form, save for blank spaces due to indentations of the sea, a nearly continuous band striking northwesterly at right angles to the courses of the axes of folding.

On the western side of the field, the basin is bounded by the bold range of the St. Anne hills composed of Pre-Cambrian and Cambrian strata rising to heights of from 500 to 1,000 feet (150 to 300 m.). In places the hills rise directly from the shore of the Great Bras d'Or channel; in other places they are separated from the waters by a narrow fringe of the Limestone series; while, towards the northeast, they are divided by a pronounced fault from a small basin of the Productive Coal Measures and older divisions of the Carboniferous.

Separated from the St. Anne range by the Great Bras d'Or channel, lies Boularderie island, about 25 miles (40 km.) long, and representing a synclinal basin mainly of Millstone Grit, this being the most westerly of the four synclinal basins of the field. To the southeast of the island and separated from it by St. Andrew channel, rise the Boisdale hills composed of Pre-Cambrian and Cambrian strata. This range extends in a S.W.-N.E. direction and represents the axial portion of an anticlinal that strikes through the northeastern extremity of Boularderie island. The Boisdale hills are in part flanked by strata of the Conglomerate series but in places members of the Limestone series repose directly on the ancient strata of the range of hills. A seeming overlap of the Carboniferous along the southeastern flanks of the range has been considered by

some as evidence of a fault striking along the southeast side of the hills and it has been held that this fault continues to the northeast through the Carboniferous basin, perhaps along the winding, river-like channel of the Little Bras d'Or. No direct evidence has been produced of the existence of such a fault and it seems more probable that the structure is due to overlapping and not to faulting.

The next anticlinal axis passes through Point Edward at the extremity of the projection separating the two arms of Sydney harbour. In a southwest direction, the course of this axis is indicated by the zone of the Conglomerate series lapping around the Pre-Cambrian strata of the Coxheath hills. Towards the northeast, beyond Point Edward, the anticlinal axis follows a course that swings to the E.N.E. and passes beneath the waters of Bridgeport basin. A fault has been described by Fletcher as extending southwestward up the valley of Sydney river on the south side of Coxheath hills. This fault in the neighbourhood of the town of Sydney has been supposed to abruptly change its direction and to run thence with a southeasterly course forming the northern boundary of a subordinate synclinal basin of strata mapped as Millstone Grit but which on palæobotanical grounds was considered by Dawson as possibly of the age of the Productive Measures.

Farther eastward, an anticlinal axis strikes inland from Cape Percy (North Head) with a W.S.W. course. This anticline apparently dies away inland. It is followed on the south by the synclinal basin of Cow bay which also dies away inland.

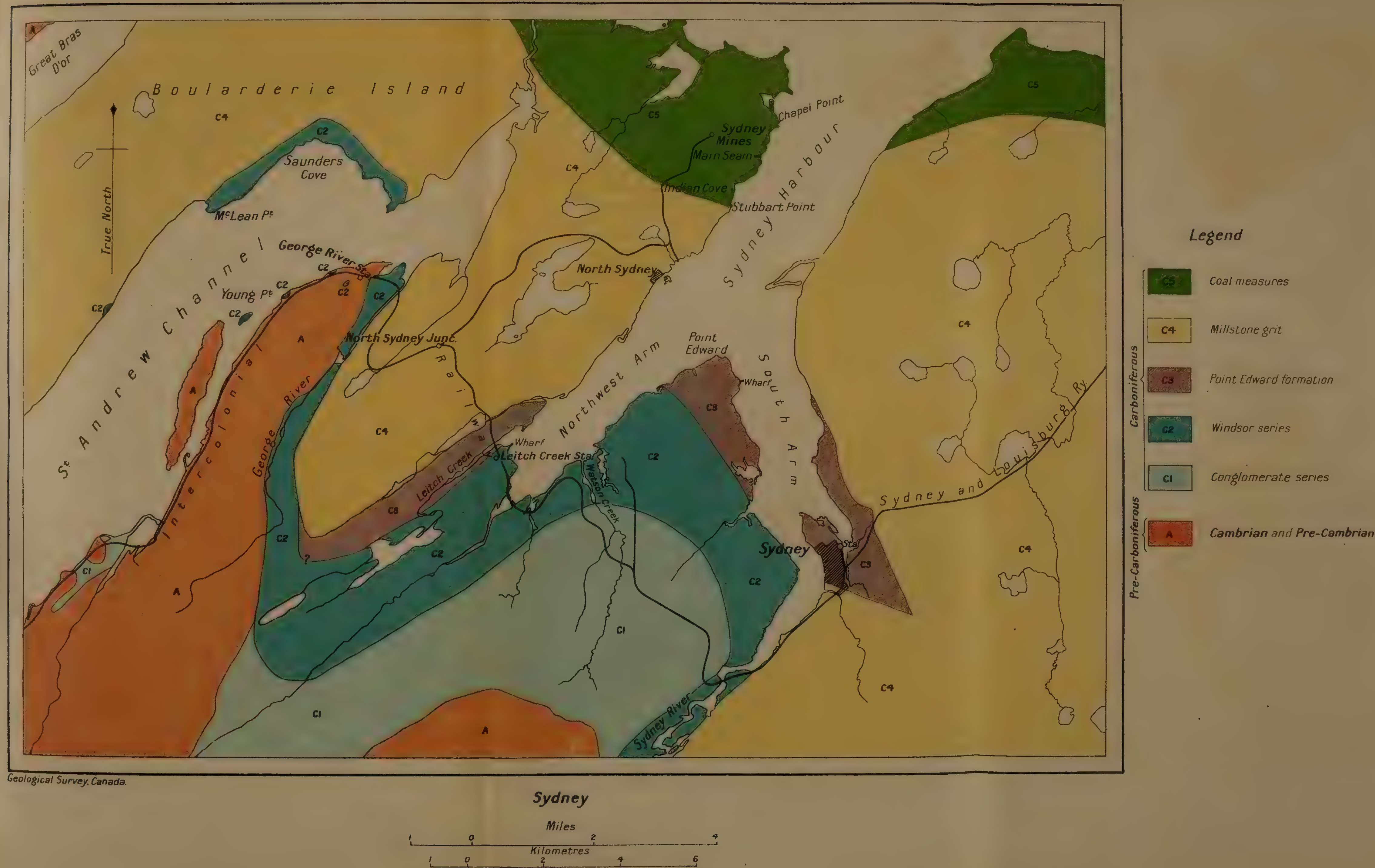
The southern margin of the western portion of the field when represented in plan on a map, indicates very clearly the position of the anticlinal axes of the Coxheath, Boisdale and Ste. Anne hills—the Carboniferous projecting southwestward in the form of synclinal basins between the axial areas of Pre-Cambrian strata. Towards the east, the basin-like structure is not so strikingly exhibited and the south boundary is formed by Millstone Grit strata resting directly on Cambrian and Pre-Cambrian beds except in the extreme east where beds of the Limestone series form the basement and are separated by faults from the Millstone Grit measures.

NOTE ON THE FLORA OF THE COAL MEASURES.

(David White.)

The palæobotany of the Sydney coal field, in Cape Breton, engaged the attention of the pioneers in palæontology in Canada. The flora was first examined by Sir Charles Lyell who, in his "Travels in North America", catalogued the fossils plants found by him at the mines. The paper by C. J. F. Bunbury, who carefully described about 50 species from Sydney in the collection of Richard Brown, is a cornerstone in the Palæozoic palæobotany of North America. Two of the excellently illustrated species, *Neuropteris rarinervis* and *Neuropteris cordata* [*Neuropteris scheuchzeri*] are most characteristic and omnipresent in the Alleghany formation and its contemporaries in the coal fields of the United States. They are present also in the lower part of the Coal Measures of many of the basins of Europe, and specimens indistinguishable from those of the second species found in Cape Breton are assocciated with some of the coals of central China. In the Appalachian trough the two species occur sparingly also in the Mercer group and within the synchronous topmost part of the Kanawha formation, but they are unknown in the older beds of the Upper Carboniferous. *Dictyopteris obliqua* and *Odontopteris subcuneata*, species founded by Bunbury, are present also in Europe as well as in the United States, where they are characteristic of a restricted zone.

The flora of the Sydney coal field was further elaborated by Dawson in a number of papers. About 115 species are reported from this coal field, but, unfortunately, the descriptions are generally so meagre and the illustrations so inadequate in most cases that the palæontologist is hardly able, merely from the examination of the reports, satisfactorily to determine the positions of the plant-bearing beds in the cosmopolitan time classification. However, it would appear from the comparison of Dawson's list that the species as a whole, cited as belonging to the "Middle Coal formation" of Cape Breton, are of slightly later date than those noted from the same formation in the Joggins section, being approximately referable to either the "transition series" or the basal portion of the Upper Coal Measures in Great Britain, and to the base of the European Stephanian, which


Great Bras D'Or
Boularderie Island
True North
Saunders Cove
McLean Pt
St Andrew Channel
George River Sta
Young Pt
North Sydney Junc.
George River
Intercolonial Railway
Leitch Creek
Wharf
Leitch Creek Sta
Watson Creek
Northwest Arm
North Sydney
Sydney Mines
Main Seam
Indian Cove
Chapel Point
Stubbart Point
Sydney Harbour
Point Edward
Wharf
South Arm
Sydney
Sta
Sydney River
Sydney and Louisburg Ry.
C1
C2
C3
C4
C5
A
Legend
C5 Coal measures
C4 Millstone grit
C3 Point Edward formation
C2 Windsor series
C1 Conglomerate series
Carboniferous
A Cambrian and Pre-Cambrian
Pre-Carboniferous
Geological Survey, Canada.
Miles
1 0 2 4
Kilometres
1 0 2 4 6

Sydney

embraces the greater part, at least, of the Alleghany formation in the Appalachian trough of the United States. Evidently several widely removed plant-bearing horizons have furnished material for the list, and it is not unlikely that some of the lower of these may be as old as the uppermost portion of the Pottsville, or perhaps the Middle Coal Measures of Europe. As belonging to the "Upper Coal formation" Dawson mentions a number of species some of which are clearly Stephanian and as high as the upper part of the Alleghany in the Appalachian coal fields.

THE CARBONIFEROUS SECTIONS ON SYDNEY HARBOUR*.

(J. E. Hyde.)

INTRODUCTION.

The section at Sydney shows the Mississippian (Sub-Carboniferous) formations, especially the Windsor series, succeeded by three Pennsylvanian (Coal-Measures) formations, the Point Edward formation, the Millstone Grit and the "Coal Measures". No other locality at present known in the eastern part of Canada shows all of these formations both so characteristically developed and with their stratigraphic succession uncomplicated by faulting or folding. Exception is not made even to the Joggins section. The Sydney section is the only section so far known in which beds with the *Leaia* fauna (the Point Edward formation which is believed to represent the Riversdale and Union) can be seen lying on the Windsor series, and overlain by the Millstone Grit. This section has determined the stratigraphical position of this fauna, although its approximate age has been known for several years.

*See Map—Sydney.

The section is as follows, from the top downward:—

Pennsylvanian system.

Productive Coal Measures.—Sandstones and shales with a number of workable coal seams and several thinner ones. Plant remains are abundant in the series; upright tree trunks are not infrequent in the shales, and roots and rootlets in position are abundant. *Anthracomya* and ostracods are abundant in the black shales associated with the coals and much the same fauna is also found sparingly in an occasional thin bed of limestone....... 1,970 ft. (600·5 m.)

Millstone Grit.—A massive, yellowish to grey, coarse, feldspathic sandstone with numerous pebble beds in the middle and lower portions; occasional thin beds of coal occur........... 3,625 ft. (1,105 m.)

Point Edward formation.—(Name new; formerly considered the top of the "Limestone series.") Alternating sandstones and shales, which are predominantly red or purplish in colour. The sandstones are characterized by cross-bedding produced by the translation ripple. Occasional limestones occur which with the shales are sometimes mud-cracked. Gypsum beds occur occasionally. A fauna consisting almost wholly of *Leaia*, a few species of *Anthracomya* and ostracods occur in the beds of grey shale. This fauna is also found, in part at least, in the Riversdale and Union formations near Truro. The Point Edward formation is correlated in a general way with those formations. According to Robb, the thickness is about............... 700 ft. (213 m.)

Mississippian system.

Windsor series.—Marine limestones and grey or red shales with occasional sandstones. This formation is not so well developed or so well shown in the Sydney section as it is in other localities on Cape Breton island. The total

thickness, which is here given, is only about half as great as the figure assigned by Robb to the same beds........................... 600 ft. 183 m.)

The following members of the Windsor series arranged in descending order, can be distinguished:—

a. Oölitic marine limestones with red shales and coarse sandstones. The limestones are marine but with a limited fauna. Thickness about................................ 211 ft. (64·3 m.)

b. Reddish shales, sandstones and conglomerate with beds of limestone which carry a fauna almost wholly of ostracods; only a few small marine lamellibranchs and gastropods are present. Thickness about................. 188 ft. (57·3 m.)

c. Sandy shales, sandstone and conglomerate, predominantly red, with at least four marine limestones, not well shown. Thickness estimated at about......................... 200 ft. (61 m.)

Age uncertain, probably Mississippian, formerly considered the lower part of the Sub-Carboniferous "Limestone series."

Red and purple sandy shales, sandstones and conglomerates all loosely coherent, with occasional thin beds of barren limestone. Pebbles up to several inches in diameter are present but they are, on the whole, not as coarse as in the formation next below. This formation was included by Fletcher in his "Sub-Carboniferous Limestone series" because of the presence of an occasional limestone bed. These are not known to carry fossils. The thickness given by Robb, which is here adopted, is probably much too large........ 2,633 ft. (802·5 m.)

Carboniferous Conglomerate series.—This was so called by Fletcher but its age is unknown. It consists of red and purplish conglomerates, differing mostly from the overlying beds in their greater coarseness.

In degree of consolidation, distribution, amount of folding, etc., it belongs to the overlying series and is probably not far removed from it in age. It rests on highly metamorphosed Cambrian and Pre-Cambrian rocks and was evidently deposited in basins between hills of these old rocks, or on the slopes of such hills. Thickness, according to Fletcher.............................. 2,525 ft.
(769·6 m.)

The rocks about Sydney harbour lie in a broad anticline which pitches to the northward. The axis of this anticline runs along the western side of the broad peninsula which lies between the east and west arms of the harbour. The section is best shown beginning with the oldest rocks on the brooks south of the west arm of Sydney harbour, thence continuing along the east shore of this arm to Point Edward. From there it can be followed, after a long interval covered by the water, along either the east or west shores of the main harbour.

DETAILED DESCRIPTIONS.

The Basal Division of the Windsor Series.—At Point Edward post office are located the quarries of the Nova Scotia Steel and Coal Co., one of the principal sources of limestone for the iron furnaces. At the road crossing at the end of the branch railway leading to the quarries is the southern margin of the belt of Windsor rocks. To the southward, in the distance, rise the high Coxheath hills of resistant Pre-Cambrian and Cambrian metamorphic and plutonic igneous rocks. These hills are probably of pre-Carboniferous age. The broad belt of rather low land intervening between these hills is underlain by the slightly resistant, loosely consolidated conglomerates and sandstones of the lower part of the Carboniferous section which overlap on to the Pre-Cambrian hills and dip northward. These conglomerates constitute Fletcher's Conglomerate series and the lower part of his Limestone series.

Proceeding westward, down the road to the shore, the first rocks seen are the topmost beds of the loosely consolidated sandstones and conglomerates just mentioned.

They are here much finer than to the southward nearer the source of the material of which they are composed. Overlying these sandstones is the basal bed of the Windsor series proper, a massive grey limestone 10 feet (3 m.) thick which forms a prominent point projecting into the bay.

In the following paragraphs, the beds of the basal member (c) of the Windsor series are numbered in ascending order, as they occur along the shore northwards.

1. Massive grey oölitic limestone, which forms a prominent point projecting into the bay. Occasional fossils, chiefly *Producti*, occur. This is bed 51 of Robb's section at Sydney.....10 ft. (3 m.)
2. Red clay shales with thin limestones, very poorly shown along the shore just north of the last point; about....40 ft. (12·2 m.)

(Beds 3 to 8 inclusive are exposed on the shore just south of the old wharf.)

3. Coarse sandstone and conglomerate with red shale......................4 ft. (1·2 m.)
4. Grey nodular limestone, greenish and black shale........................8 ft. 10 in. (2·7 m.)
5. Thin, soft, coarse sandstone with plant remains..........................2 ft. 6 in. (1·4 m.)
6. Bluish grey nodular limestone; fossils abundant and surrounded by concentric deposits of limestone which are apparently original. One of the best fossils beds of the section.......2 ft. 4 in. (0·7 m.)
7. Sandy shales with abundant concentric nodules containing *Producti*.........2 ft. 2 in. (0.6 m.)
8. Light grey, thinly bedded limestone with *Producti*......................9 ft. (2·7 m.)

The next set of beds in the section are exposed in the old Louisburg quarry situated 75 metres inland at the end of an abandoned road.

9. Thinly bedded, grey, finely oölitic limestones with *Producti* abundant in pockets and layers. These beds overlie those (No. 8) seen on the shore but it is not exactly known whether or not the basal beds in the quarry are shown on the shore. It is reported that limestone was once quarried here for use in the building of Louisburg. Thickness at least.................... 13 ft. (3·9 m.)

Leaving the Louisburg quarry ,and continuing eastward up the hill, along the strike of the quarry bed, past the old lime kiln, and from there along a more northeasterly course descending into a small shallow stream valley the next two beds may be noted.

10. Massive pink limestones, single bed 2 ft. 2 in. (0·6 m.)
11. Massive very finely oölitic limestone 6 ft. 6 in. (2·0 m.)

Crossing the marshy stream in the shallow valley, the line of section continues up the hillside over a covered interval to the base of the main quarry.

12. Covered, but known to carry near the middle a massive limestone 9½ feet thick (2·9 m.) and at the top 15 feet (4·5 m.) of coarse sandstone with plants, the top of which can be seen at one point in the quarry. About..... 70 ft. (21·3 m.)

The following beds are exposed in the large quarry of the Nova Scotia Steel and Coal Company.

13. Grey oölitic limestone with concentric nodules, resting on the sandstone mentioned under No. 12............ 2 ft. 7 in. (0·8 m.)
14. Sandy shale with abundant hard concentric limy nodules in which fossils occur.......................... 1 ft. 6 in. (0·4 m.)

15. Massive oölitic limestone, fossils very rare except in basal two feet where *Productus* is fairly common. In places the limestones show the concentric structure prominently and in such a manner as to suggest that it is an original structure of the limestone. This is the topmost bed of division C of the Windsor limestones............32 ft. 8 in. (10 m.).

Fauna of the Windsor Series.—The fauna of the Windsor series as developed at Sydney differs considerably from the fauna found in these limestones at Windsor, N.S., but several of the species are identical and there is no question as to the general equivalence of the beds. On the other hand, many species appear which have not been recorded from Windsor. These differences appear to be due, in considerable measure, to the variation of the fauna from point to point. The following notes are the results of a preliminary study and are subject to considerable revision and amplification. The propriety of using some of the specific names here adopted is very doubtful. For example, "*Dielasma sacculus*" Martin, is certainly not present. But the form here so designated has almost always been so referred to, and a different name cannot be adopted without much discussion.

The faunas of the three members of the Windsor series differ considerably. That of the uppermost member is a pure marine fauna with corals, *Productus*, *Schuchertella*, *Camarotœchia*, *Spirifer*, *Spiriferina*, *Composita*, "*Dielasma sacculus*", several species of marine lamellibranchs and gastropods, and other species.

That of the middle member is also marine but evidently developed under restricted or special conditions. Several species of ostracods, *Spirorbis*, two or three species of small aviculoid and alate lamellibranchs, a small gastropod and the Foraminiferal species (?) *Nodosinella priscilla* Dawson, comprise the whole of the fauna so far observed.

The fauna of the lower member, as developed near Point Edward Post Office, evidently existed under more nearly typical marine conditions than did that of the middle member but no such diversified fauna has been observed as is found in the upper member. Whether this is due to biotic conditions or difference in age cannot as yet be stated. The lower member is marked by numerous species of *Productus* and by the alate lamellibranchs.

Rather striking, also, is the restriction of the faunules in the several beds and the appearance of different species in these beds. This tendency, the limitation of and difference in the faunules in successive beds, is believed to be due to varying biotic conditions.

Several species are common to the lower and upper members of the Windsor, among them *Productus* cf. *arseneaui*, *Productus laevicostus*, *Pugnax dawsonianus*, and *Dielasma sacculus*.

One species only has been found common to the Point Edward formation and the Windsor series, the ostracod here called *Beyrichiopsis granulata* var, which is so strikingly distinct as to be easily recognized. It occurs in several beds of the Windsor, ranging from the basal bed of the lower member into the middle of the middle member.

In the whole Windsor series of this section, there is only one bed and one locality, so far observed, where fossils are abundant. This is in the upper member. Usually they are scarce, and not infrequently they are to be obtained only after a long and patient search.

Following is a list of the species obtained in the lower member at the Point Edward Post Office locality. The numbers at the top of the columns are the ones used to designate the beds in the detailed section already given.

——	Basal Part. I	Upper Part. I	6	7	9	14	15
Serpulites annulatus Dawson	....	x	....	....	....	....	....
Spirorbis sp	....	....	....	....	....	x	....
Productus cf. arseneaui Beede	....	....	x	x	....	....	x
Productus auriculispinus Beede	x	....	....	....	....	....	....
Productus dawsoni acadicus Beede	....	....	x	....	....	....	....
Productus laevicostus White	....	....	....	x	....	....	....
Productus tenuicostiformis Beede	....	....	....	....	x	....	x
Productus sp	....	x	....	....	....	x	....
Pugnax dawsonianus Davidson	....	x	....	....	....	....	....
'Dielasma sacculus Martin'	....	x	....	....	....	....	x
Aviculopecten sp	....	....	x	....	....	....	....
Aviculopecten cf. debertianus Dawson	....	....	....	....	x	....	....
Leptodesma sp	....	....	x	x	....	....	....
Leiopteria dawsoni Beede	....	....	....	....	x	....	....
Gastropod gen. et sp. (*a*)	....	....	....	x	....	x	x
Gastropod gen. et sp. (*b*)	....	....	x	....	....	....	....
Orthoceras sp	....	....	x	x	....	....	....
Endolobus avonensis Dawson	....	....	x	....	....	....	....
Ostracods	x	....	x	x		x	x
Beyrichiopsis granulata J. and K. var	x	....	....	....	....	....	....

Point Edward Post Office to the Quarantine Station on Point Edward.—The branch railway from the limestone quarries at Point Edward post office, runs southward to join the main line of the Intercolonial railway. This branch railway passes on the western side of the north-easterly pitching anticline whose position is marked to the south by the Pre-Cambrian area of the Coxheath hills around which the Lower Carboniferous beds are symmetrically disposed. Leaving the quarries, the railway passes through a belt of northerly and gently dipping red and purple, sandy shales, sandstones and conglomerates underlying the Windsor series and forming part of the original Limestone series. Farther south, the branch railway enters the area of reddish conglomerates of the Conglomerate series which extends southward over and around the Pre-Cambrian rocks of the Coxheath hills.

From the point of junction of the branch railway and the main line, the Intercolonial railway runs in a northeasterly direction towards and then around the head of the Northwest Arm of Sydney harbour. Along this course the railway passes over the Carboniferous strata in ascending order as they occur on the western limb of the Point Edward anticline. For some distance west of the railway junction, the underlying strata belong to the Conglomerate series; beyond this occur the measures of the Limestone series outcropping along the eastern shore and about the head of the Northwest Arm. The strata dip to the northwest at angles of 5° to 20°. In the vicinity of Leitch Creek station, the measures belong to the Windsor division of the Limestone series; beyond this, on the western shore at the head of Northwest Arm, the strata belong to the Point Edward division which farther west along the railway are succeeded by Millstone Grit beds.

Proceeding by boat from Leitch Creek station, northward down the waters of Northwest Arm, low outcrops of the Point Edward formation may be observed in the banks on the west. These dip to the west under the Millstone Grit which forms the high hills a few hundred metres beyond the shore. The Point Edward formation is only shown for a short distance, when it passes entirely below the Millstone Grit. The contact is a sharp one, and is moderately well shown. From the contact northward to beyond North Sydney, outcrops of the Millstone Grit are more or less continuous on the west bank. On the east

shore, the contact between the Windsor series and the Point Edward formation lies between the two closely located light houses. Northward from these lights occasional low outcrops of the Point Edward formation may be seen, in ascending order. Rounding Point Edward, outcrops in descending order continue southward to the landing pier at the Quarantine station.

The Point Edward Formation.—On the farther side of the first little bay north of the landing pier, a bed of dark grey shale furnishes the typical fauna of the Point Edward formation, including *Leaia*. At the point beyond, mud-cracked limestones, red shales and reddish and purplish sandstones typical of the Point Edward formation, may be observed. The sandstones are characterized by cross bedding, the result of translation ripples. Plant fragments are abundant and branches several feet in length are not unusual. There are also peculiar vertical tubes distributed abundantly through the sandstones, the origin of which is uncertain.

Section of Millstone Grit and Coal Measures in the Vicinity of North Sydney. The Millstone Grit and Coal Measures form a thick, conformable series outcropping on the western shore of Sydney harbour and Northwest Arm from Limestone creek on the south to Cranberry head on the north. Throughout this whole section, which has a length of about 7½ miles (12 km.), the strata dip at angles of from 5° to 15° to the north and north-northwest. The total thickness of measures displayed is about 5,350 feet (1,830 m.) of which the upper 1,725 feet (525 m.) belong to the Coal Measures. The Millstone Grit strata are almost entirely grey sandstones which towards the base of the formation are conglomeratic, while at the summit they are interbedded with variously coloured shales. One coal seam, with a thickness of about 2 feet (0·6 m.) occurs in the Millstone Grit towards the top of the formation. The Coal Measures consist of grey sandstones, dark and variously coloured shales, thin limestones and numerous coal seams which individually are as much as 6 feet (1·8 m.) thick, and have a combined thickness of nearly 42 feet (12·8 m.).

The exposures of Millstone Grit to the southward of North Sydney are monotonously alike. The upper part of the formation is well exposed along the shore to the northward of the town and the strata there are quite

typical of the whole formation except that conglomeratic beds are not present. The contact of the Millstone Grit with the Coal Measures is a conformable one and is excellently shown. The somewhat arbitrarily chosen boundary between the two formations is indicated by a rather abrupt change from the light colour of the sandy measures of the Millstone Grit to the much darker, shaly strata of the Coal Measures. An upright tree trunk, several feet in height is shown (in 1912) in cross section a short distance beyond the contact.

Immediately north of the piers at Indian Cove, and in the shales overlying the Indian Cove coal seam, abundant

Coal measures, Sydney, N.S. Looking north from "Main seam" outcrop.

fern remains may be found. Long Stigmaria roots are found in these shales with rootlets radiating in all directions in position as they grew. In the coarse sandstones overlying this shale bed, are abundant upright Calamite stalks up to two feet in length. Continuing up the shore, a monotonous succession of sandstones, red shales, grey shales, coals, etc., is traversed. The red shales are mud-cracked; the grey shales commonly carry rootlets; the black shales associated with the coals usually show abundant ostracods and *Anthracomya*. An occasional thin bed of limestone is exposed, one bed of which is known to carry fragmental fish remains in abundance.

Just before the "main seam" is reached, upright tree trunks and roots are found in abundance in one of the shale beds. The "main seam" is indicated by old workings and excavations, but its very top may be seen if tidal conditions are favourable. The shales overlying it have furnished many species of plants. A few metres beyond the main seam, *Anthracomya* and ostracod s, may be found in black shales in an old excavation in the cliff.

BIBLIOGRAPHY.

1. Brown, R........Quart. Journ. Geol. Soc. Lon., Vol. I, pp. 207–203, 1845: Vol. II, pp. 293–6, 1846: Vol. III, pp. 257–60, 1847: Vol. IV, pp. 46–50, 1848: Vol. V, pp. 354–60, 1849: Vol. VI, pp. 115–133, 1850.

2. ....Coal Fields and Coal Trade of the Island of Cape Breton, London, 1871.

3. Bunbury, C. J....Quart. Journ. Geol. Soc. Lon., Vol. III, pp. 423–437, 1847: Vol. VIII, pp. 23–26, 1852.

4. Dawson, W. J....Quart. Journ. Geol. Soc. Lon., Vol. XXII, p. 95, 1866.

5. ....Canadian Naturalist, Vol. VIII, p. 431, 1863.

6. ....Geol. Surv. Can., Fossil Plants of the Lower Carboniferous and Millstone Grit, 1873.

7. ....Acadian Geology.

8. Fletcher, Hugh...Geol. Surv. Can., Report of Progress, 1875–76; Report of Progress, 1876-77

9. ....Geol. Surv. Can., Descriptive Note of the Sydney Coal Field, 1901.

10. Gilpin, E........Proceed. and Trans. Nova Scotian Inst. Sc., Vol. VIII, pp. 435–8, 1895.

11. Lesley, J. P......Amer. Journ. Sci. and Arts, 2nd ser., Vol. XXXVI, p. 179, 1863.

12. ....Proceed. Amer. Phil. Soc., Vol. IX, pp. 93–109, 1865.

13. Robb, C.........Geol. Surv. Can., Report of Progress, 1872–73: Report of Progress, 1873–74: Report of Progress, 1874–75.

ANNOTATED GUIDE.

SYDNEY TO GEORGE RIVER STATION.

(G. A. Young.)

Miles and kilometres.

0 m.
0 km.

Sydney.—Leaving Sydney station, the Intercolonial railway, before passing out of the city crosses the fault line forming the boundary between the area of Carboniferous Limestone series on which the city is built and the wide area of Millstone Grit extending far to the south and east. After leaving the city proper, the railway passes close to the shores of the estuary of Sydney river. Occasional outcrops of Millstone Grit occur along the shore, the strata dipping to the southeast at angles of from 15° to 35°. Strata of the Limestone series, also dipping to the southeast, are exposed on the opposite side.

Three miles (4·8 km.) from Sydney, the railway crosses Sydney river. The low valley of the river extends with this character for a number of miles to the southwest and is floored with strata of the Carboniferous Limestone series, the measures dipping to the southwest. At the crossing of Sydney river, the band of the Limestone series is less than ½ mile (0·8 km.) wide and the railway in a short distance passes into an area occupied by the Carboniferous Conglomerate series. The strata of the Conglomerate series are arranged in anticlinal form about a ridge of Pre-Cambrian strata which rises several miles southwest of the railway. The reddish conglomerates, sandstones and shales of the Conglomerate series dip at low angles, away from the central ridge of Pre-Cambrian rocks and are flanked on the east, north and west by apparently conformable strata of the Limestone series.

Three miles (4·8 km.) beyond the crossing of Sydney river, the railway passes over a low summit situated approximately on the anticlinal axis of the fold in the Carboniferous strata,

Miles and Kilometres.

and begins a traverse of the northwestern limb of the anticline. In a distance of about 2 miles (3·2 km.) from the summit, the railway again enters the encircling area of the Limestone series and shortly approaches the shores of the Northwest Arm of Sydney harbour around the head of which the railway passes. The low valley at the head of the Northwest Arm is floored by strata of the Limestone series dipping to the northwest at angles of from 15° to 25°.

10·4 m. 16·7 km. **Leitch Creek Station**—Alt. 10 ft.(3 m.). A short distance beyond Leitch Creek station, at the crossing of Leitch creek, a view up the valley shows the ridge of the Boisdale hills rising to altitudes of 600 to 800 feet (180 to 249 m.). The Boisdale hills are composed of Pre-Cambrian rocks and form the western boundary of the Carboniferous basin. The Carboniferous Limestone measures extend up the valley of Leitch creek and there repose directly on the Pre-Cambrian rocks without any intervening strata of the Conglomerate series.

A short distance beyond the crossing of Leitch creek, the railway passes through cuttings in reddish shales and sandstones possibly belonging to the Point Edward formation which in places lies between the Limestone series and the Millstone Grit. Just beyond this point, where the railway skirts the shores of a small lake, the area of Millstone Grit strata forming the summit of the western limb of the anticline, is entered upon. Small cuttings in Millstone Grit strata occur along the railway. The measures dip to the northwest at angles of 10° to 20°. The Millstone Grit strata form a ridge exending in a northeast-southwest direction and in which the strata are arranged in a shallow syncline. To the southwest, the Millstone Grit strata are encircled by measures of the Limestone series which rest on the Pre-Cambrian rocks of the Boisdale hills. To the northwest, the Millstone Grit

Miles and Kilometres.

beds dip beneath the Coal Measures of the North Sydney area.

12·9 m. 20·8 km. **North Sydney Junction**—Alt. 159 ft. (48·5 m.). North Sydney Junction is situated approximately on the axis of the synclinal fold traversing the Millstone Grit area. From this point, the waters of St Andrew channel are visible to the northwest, with the low wooded heights of Boularderie island beyond, while above these are visible the highlands on the western side of Great Bras d'Or. These highlands, distant about 9 miles (14·5 km.) rise to altitudes of 900 feet (275 m.) and form the western boundary of the Sydney Carboniferous basin. Boularderie island is mainly occupied by Millstone Grit strata arranged in a shallow syncline with strata of the Limestone series occurring at intervals along the southeastern and northwestern shores. The anticlinal axis separating the Boularderie Island syncline from the North Sydney syncline is, in a general way, the prolongation of the axis of the Boisdale hills.

Leaving North Sydney Junction, the railway descends towards the valley of George river. The Boisdale ridge rises on the further side of the river valley and after passing a small lake, a quarry working in Pre-Cambrian crystalline limestone is visible on the side of the ridge. The western side of the valley of George river is floored with strata of the Carboniferous Limestone series dipping to the east. The total thickness of this series as developed in this neighborhood is small as compared with the development on the shores of Sydney harbour. Possibly the decreased thickness is due either to faulting or to an overlap of the Millstone Grit.

The railway crosses George river near its mouth and enters the narrow area occupied by the Limestone series. The railway passes close to the shore around the northern end of

Miles and Kilometres.

the Boisdale ridge and after leaving the area of the Carboniferous Limestone series, it crosses Pre-Cambrian granite which extends westward beyond George River station.

16·6 m 26·7 km. **George River Station**—Alt. 37 ft. (11·3 m.).

GEORGE RIVER.*

(G. A. Young.)

INTRODUCTION.

The line of the Intercolonial railway eastward and southward from George River station affords an opportunity of examining a part of a section transverse to the axis of the Boisdale hills at the northern end of this upland. This range of hills is largely underlain by Pre-Cambrian and Cambrian strata with detached areas of Carboniferous measures outcropping along their flanks.

The Boisdale hills follow a S.W.–N.E. course for a distance of about 30 miles (48 km.) and vary in width from 6 miles (9·6 km.) in the southern portion to about ½ mile (2·4 km.) at the northern end. Along their northwestern side, the hills rise steeply, in places abruptly, from the waters of Bras d'Or lake, to heights of 600 feet (180 m.) to 900 feet (275 m.) above sea level. Along their southeastern side, the hills in the north are bounded by the lowlands of the Sydney Carboniferous basin, while towards the south they rise directly from the shores of East bay, a northeasterly extension of Bras d'Or lake.

The strata outcropping in the Boisdale hills have been mapped and grouped by Fletcher [**1**] as follows:—

Carboniferous	Carboniferous Limestone series. Carboniferous Conglomerate series.
Pre-Carboniferous	Cambrian. Pre-Cambrian, George River series. Pre-Cambrian, granite, gneiss, schist, etc.

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*See Map—George River Station.

The Pre-Carboniferous strata, at first considered to represent metamorphosed Carboniferous measures intruded by granitic bodies, were next thought to be of Silurian age, and finally, by Fletcher were mapped and described as divisible into Lower Silurian (*i. e.* Cambrian) and Pre-Cambrian. Later still Matthew subdivided the Cambrian into five divisions and placed in the Cambrian certain strata previously considered to be of Pre-Cambrian age.

The Pre-Cambrian strata as mapped by Fletcher, occupy by far the larger part of the area of the Boisdale hills. The Carboniferous beds occur only in the form of a narrow, discontinuous border. The Cambrian beds are mainly confined to a long, narrow zone which in the north forms the western margin of the upland but in the south, extends from side to side of the Pre-Cambrian area.

The Pre-Cambrian was divided by Fletcher into two groups. One of these was termed the George River series and because of its lithological characters was supposed to be the equivalent of the Grenville-Hastings series of Quebec and Ontario. This view was adopted by Matthew also. As described by Fletcher, the George River series consists of crystalline limestone, quartzite, mica schist, hornblende schist, etc., interleaved with granitic and gneissic rocks. The strata in most places, are inclined at high angles and are highly metamorphosed. The series was regarded as essentially of sedimentary origin and was believed to be younger than, and to rest unconformably on the associated granitic rocks. This view of the relations existing between the sedimentary series and the plutonic rocks was doubltess based on the beliefs, held in the 70's at the time the field work was performed, regarding the relations existing in the typical Laurentian areas of Quebec. Recent examinations made of some typical sections of the George River series indicate, however, that the granitic rocks unmistakably cut and are younger than the George River series. The correlation on lithological grounds of the George River series with the Laurentian (Grenville-Hastings) of distant Quebec is perhaps no longer justifiable. But the various points of resemblance existing between the Pre-Cambrain of Cape Breton and the original Laurentian, are worthy of note.

The George river series as mapped by Fletcher is confined to three, long, detached areas situated along the south-eastern flank of the Boisdale hills. These areas border the great central mass of the ranges regarded by Fletcher as essentially occupied by granite but including large and small areas of rocks that in some cases possibly belong to the George River series and in others to the Cambrian. As already stated, it is now advocated that the granitic rocks are younger than the George River series. It is assumed, therefore, that the Pre-Cambrian of the Boisdale hills consists of the remnants of one or more series of limestones, quartzites, etc., and possibly deformed volcanics, intruded by bodies of granitic rocks. In the extreme northern portion of these hills, the granites form relatively large, homogenous areas from which offshoots extend into the older, bedded series.

The Pre-Cambrian age of the above described assemblage of strata has been established by Fletcher, who stated that Cambrian conglomerates hold rock fragments similar to varieties of rocks in the Pre-Cambrian, and that the Cambrian is nowhere cut by the granites. Examples of the actual unconformable superposition of the Cambrian on the Pre-Cambrain have been described by Fletcher and Matthew. In general, however, the two rock groups are in contact along faults.

The Cambrian measures as mapped by Fletcher, form a long, narrow band extending nearly the whole length of the Boisdale hills. As described by Fletcher, the Cambrian consists of a series of sediments and, also, a group of igneous rocks generally described under the name of 'felsites.' On an earlier map, a considerable area of these igneous rocks is unquestionably included in the Cambrian. On a later map, a portion of these igneous rocks is mapped separately. The relation of these igneous rocks to the Cambrian sediments is not specifically described by Fletcher, nor is it very apparent on what grounds certain 'felsites' were mapped as Cambrian while others were assigned to the Pre-Cambrian. Matthew has definitely grouped certain of the igneous rocks with the Cambrian, including some that by Fletcher were considered Pre-Cambrian.

Matthew has subdivided the Cambrian, on paleontological and lithological evidence, into five groups. The

following table is a condensed form of one published by Matthew [**2**, p. 69].

		Equivalents in Great Britain.
Ordovician.	Bretonian.	Llandeilo.
		Arenig.
Cambrian.		Tremadoc. Dolgelly.
	Johannian.	Maenterog.
		Ffestiniog.
	Acadian.	Menevian.
		Solva.
Basal Cambrian.	Etcheminian.	Caerfai
	Coldbrookian.	Pebidian.

The *Coldbrookian* is described by Matthew as essentially composed of volcanic rocks comprising flows and tuffs. In places it is found lying unconformably upon the Pre-Cambrian with a coarse conglomerate at the base. At one locality only, are fossils described as occurring in the Coldbrookian. At this locality, on Dugald brook, about 20 miles (32 km.) southwest of George River station, the Coldbrookian is only 315 feet (96 m.) thick. The lower portion is of feldspathic sandstones with layers of conglomerate. The upper portion consists of amygdaloids and felsites. Above these occur members of the Etcheminian division. The fossiliferous strata lie midway in the section and are about 30 feet (9.1 m.) thick. Six species of brachiopods and two of ostracods are described by Matthew [**2**, p. 72]. The two ostracods occur also in the overlying Etcheminian accompanied by brachiopods very similiar to those found in the Coldbrookian.

The typical region for the Coldbrookian series is in southwestern New Brunswick, where, so far as is known, the

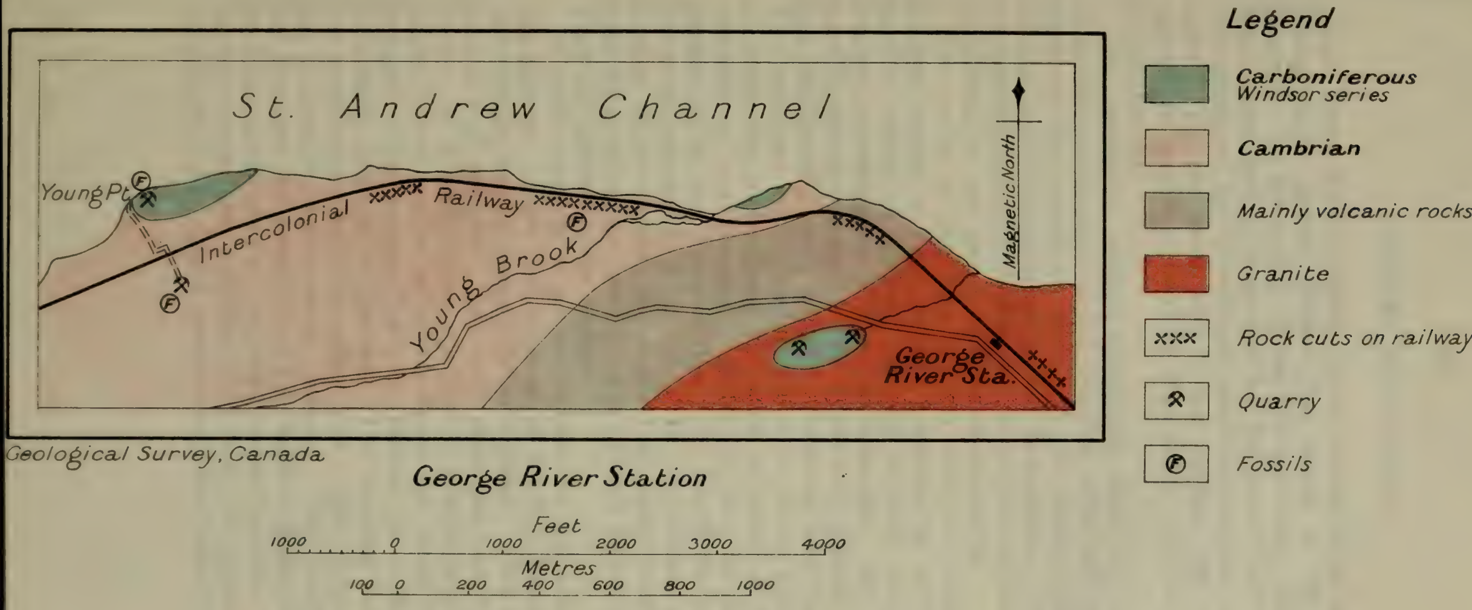
rocks of this group are all igneous and have generally been considered to belong to the Pre-Cambrian. The correlation of the strata in the Boisdale Hills has been based, (1) on supposedly similar stratigraphical relations and (2) on similarity in appearance.

The *Etcheminian* is described as essentially a sedimentary formation divisible into a lower and upper division. The lower division consists largely of red and grey slates and sandstones with conglomerate beds. The upper division is composed mainly of grey, fine and coarse, shales and slates. Both divisions are fossiliferous and besides a number of species of brachiopods and osteracods, Matthew has listed a trilobite "apparently related to Asaphus" (*Holasaphus centropyge*), a Paradoxoid trilobite and one of the genus Solenopleura.

The *Acadian* division consists chiefly of dark grey slates. It is unfossiliferous in the Boisdale hills area. The *Johannian* is composed mainly of grey slates, sandstones and quartzites and has produced some fossils, among them, *Paradoxides forchhammeri*, and a number of inarticulate brachiopods. The *Bretonian* division is chiefly formed of dark grey and black slates; among the few fossils that have been found are species of Asaphellus, a typical 'Tremadoc' genus. On the Mira river, the Bretonian is much more richly fossiliferous and contains faunas, strictly comparable to the Scandinavian Upper Cambrian and Lower Ordovician.

Matthew gives [**2**, p. 52) the following estimate of the thickness of the Cambrian as developed respectively in the Boisdale Hills area and in the Mira River valley not many miles to the east.

	Boisdale hills.	Mira river.
	Feet.	Feet.
Bretonian	500	500
Johannian	1,200	2,000
Acadian	200	800
Etcheminian	500	3,000
Coldbrookian	300	very thick.



George River Station

(Scale of map is approximate)

DETAILED DESCRIPTION.

The Intercolonial railway from George River station to Young point closely follows the shores of St. Andrew channel. To the north, across the waterway, lies Boularderie island mainly underlain by Millstone Grit measures with strata of the Limestone series outcropping along the shores. On the south side of the railway the land rises quickly to heights of 600 feet (180 m.) to 700 feet (215 m.) above the sea.

The geological section developed along the railway is transverse to the axis of the Boisdale hills and cuts across them at their northern end. At the eastern end of the section, the Pre-Cambrian granite is exposed. Proceeding westward, the granite is followed, according to Matthew, by Coldbrookian and then by Etcheminian strata.

The rocks in the first cutting east of George River station consist of pink granite traversed by a number of parallel dykes of diabase dipping at high angles. The granite is presumably of Pre-Cambrian age; the dykes are possibly much younger. The dykes vary greatly in width and individually send parallel off-shoots into the granite. The rocks are much fractured and, in places sheared. As a result, the rocks along the walls of some of the dykes resemble a conglomerate. Referring to the basal conglomerate of the Etcheminian, Dr. Matthew makes the following statement [**2**, p. 17]; "In the railroad cutting at George River station the contact of these conglomerates with the syenite (i.e., granite) can be seen at several places. They fill hollows in the syenite."

A small outcrop of granite occurs on the south side of the railway, a short distance west of the first brook crossing the railway west of George River station. This is the last exposure of granite. The rock does not outcrop on the shore. It is visible at a number of points on the eastern slopes of the valley in which flows the small brook just crossed. The granite body is known to extend for an indefinite distance southward. The western boundary of the granite probably lies about 100 yards (90 m.) west of the isolated exposure on the railway. The relations existing between the granite and the rocks exposed in the first rock cut to the west of the brook are not known. Nowhere in the immediate neighborhood has the granite or its apophyses been found penetrating the rocks of this cut.

They may, therefore, be younger than the granite and possibly are of Cambrian age.

The first rock cut to the west of the brook exposes weathered and, in places, sheared igneous rocks. Two main rock types are present, one is represented by dense greenish black and reddish rocks apparently approaching an andesite in composition. The other type is fine-grained, greenish black in colour, and is of the composition of a diabase. The diabase closely resembles the dykes of this rock cutting the Pre-Cambrian granite in the first rock cut and is thought to be the same rock.

At the eastern end of the rock cut are a few exposures of an andesite tuff, while at the west end, there is a small exposure of conglomerate. Throughout the length of the cut, the andesite and diabase alternate. The relations of the diabase to the andesite are not known. The conglomerate at the west end of the rock cut, is penetrated by the diabase and presumably the diabase also cuts the andesite either in the form of dykes or sills.

Approaching the west end of the rock cut, on the seaward side, are exposures of reddish, shale-like rocks probably representing much decomposed andesite. On the south side, at the west end of the rock cut, is a small exposure of conglomerate composed of somewhat angular rock fragments of small size in a quartzite matrix. The rock fragments closely resemble the andesites. This conglomerate and the diabase that cuts it, mark the end of exposures of igneous rocks. The same igneous assemblage occurs on the beach north of the railway and the exposures there also terminate with an outcrop of conglomerate. In the hill country to the southwest of the railway are outcrops of the same igneous rocks as occur on the railway.

The relations existing between the igneous rocks and the succeeding Cambrian sediments is not directly known. Both on the shore and along the railway, the exposures of the two classes of rocks are separated by a concealed interval. On the shore, the concealed interval is about 250 feet (76 m.) in width. Beyond it to the west are continuous exposures of green and reddish grits, sandstones and shales of Cambrian age. The sedimentary beds are faulted and closely folded. It is assumed that they are separated from the igneous rocks on the east by a fault. The conglomerate at the west end of the rock cut possibly represents the base of a series of rocks younger than the

andesites. The conglomerate may mark the base of an older Cambrian series brought by the assumed fault against the Cambrian strata to the west. If the conglomerate is of Cambrian age, it is evident that the diabase is also of Cambrian or younger age. This would then, also be true of the dykes cutting the granite in the first rock cutting.

The igneous strata of the railway cut belong to a limited area along the border of the Cambrian basin from which they seem to be separated by a fault . There is no direct evidence that they are not of Pre-Cambrian age and they may be older than the Pre-Cambrian granite. Dr. Matthew writing of the basal conglomerates of the Etcheminian, makes the following statement [**2**, p. 17] regarding the rocks exposed along the railway cut just traversed: "......the conglomerates are seen to rest on dark purplish-grey, fine grained felsite similar to those of Long island and presumably of the Coldbrookian terrane......" The so-called Coldbrookian on Dugald brook, 20 miles (32 km.) to the southwest, contains a fossiliferous zone with Cambrian fossils.

To the west of the above described rock cut, approaching Young brook, a few exposures of Cambrian sediments occur close to the railway. From the culvert over Young brook, the Cambrian measures are visible in low cliffs extending eastward along the shore. The strata consist of grey, green and reddish slates, sandstones and fine conglomerate faulted, folded and crumpled. Fossils, almost all inarticulate brachiopods belonging to the genera Lingulella and Lingulepis, are abundant in these strata along the shore west of Young brook and are present, though less common, in some of the strata east of the culvert. Regarding these strata, it has been stated [**2**, p. 17] that the reddish and purplish beds belong to the lower division of the Etcheminian and are cut off by a fault at Young brook from the grey strata of the upper division exposed to the west along the shore and railway as far as Young point.

In the first rock cut beyond Young brook occur greenish shales and sandy beds with others of lighter coloured sandstone, also some dark shales. Near the beginning of the rock cut, a synclinal crumple is visible. Beyond this, the strata dip in a fairly constant direction, inland, at high angles.

At about the centre of the rock cut are a number of thin beds (8 inches and less) of fine, grey sandstone containing

brachiopods, etc. The same general strata are also exposed in the low cliff along the shore on the north side of the railway.

In the next rock cut are exposed crumpled dark slates accompanied by torn bands of fine sandstone. A short distance further, a small rock cut passes through dark greenish slates with very thin beds of sandstone.

To the south of the railway, the same general strata are exposed with a general strike towards the northeast but faulted, crumpled and closely folded. On the shore, to the north of the railway, the shaly strata are also crumpled and torn.

In the small quarry on the north side of the railway at Young point, is exposed a face of dark slates interbedded with sandstone bands carrying fossils, *Lingulepis roberti* is the common fossil. The strata are bent into an anticlinal fold. On the higher slopes of the hill, above the quarry opening, are outcrops of greenish slate and in places, coarse and fine sandstone beds some of which are fossiliferous. The strata are much disturbed. In places they are minutely crumpled; in other places they lie in small folds whose axes are separated by intervals of 5 feet to 10 feet (1·5 to 3 m.). The strike is, as before, fairly constant and follows a general northeast course.

At Young point there is a small quarry in Carboniferous limestone, which fills a depression in the eroded surface of the highly tilted Cambrian shales. Similar pockets of Mississippian limestone with fossils occur on the eastern side of the valley south of the railway near George River station and elsewhere. The limestone is fossiliferous and at Young point, mingled with the Carboniferous types are Cambrian forms derived from the underlying strata. The following note has been prepared by J. E. Hyde:—

"The following species have been obtained from the Windsor limestone resting on the old land surface near George River station, at Young point and in the two small quarries back of the station. Those species which are marked with an asterisk (*) are the more characteristic of the faunule, although only one, *Dielasma sacculus*, is very abundant. By far the greater part of these species were obtained at Young point but the limestone at the two other pockets carry the same fauna, in so far as it is developed. Six of the 12 species have not been observed in the Point Edward or Sydney section, namely 1, 6, 7, 8, 9, and 11"

1. Auloporoid coral sp. undt.
2. *Serpulites annulatus Dawson.
3. Productus sp.
4. Schuchertella sp.
5. *"Dielasma sacculus Martin."
6. Edmondia cf. magdalena Beede.
7. *Leptodesma sp. cf. Leiopteria acadica Beede.
8. *Pteronites sp.
9. *Loxonema sp.
10. Orthoceras cf. indianense Hall.
11. *Conularia planicostata Dawson.
12. Ostracods.

The Cambrian consists of purplish and greenish shales with thin layers and beds of purplish weathering sandstone and grit. Similar strata outcrop along shore for about 1,000 feet (300 m.). The beds are traversed by small faults and dip in various directions usually at high angles. The folding and faulting is such that practically everywhere the same horizon is exposed and a three to four-foot bed of coarse sandstone or fine grit in various attitudes is exposed at a number of places. Beyond this, the above measures give place to greenish shales crenulated and closely folded.

At Young point some of the sandy beds are rich in brachiopods. From these measures Dr. Matthew [**2**, p.19] has listed the following species:—

Leptobolus atavus.	Billingsella retroflexa.
Lingulella selwyni.	Holasaphus centropyge.
Lingulepis roberti.	A paradoxidoid trolobite.
Obolus discus.	A eurypterid? crustacean.

This is the type locality for the trilobite genus *Holasaphus*, and specimens of the typical species (*cranidia* and *pygidia* are quite abundant in the shale just north of the quarry.

Regarding the fossils from this locality, Matthew states [**2**, pp. 18-19] that on examining an earlier collection it was thought that they were of Lower Ordovician age. But as a result of a personal visit to the locality, he became convinced that "the beds, in place of being at the summit of the Cambrian, are towards its base. and are in fact of the lower division of the Etcheminian." Recently the

writer and Dr. P. E. Raymond obtained *Paradoxides forchhammeri* from the Young Point beds. The finding of this species, as pointed out by Dr. Raymond to the writer, indicates that the measures belong to the highest of the Middle Cambrian Paradoxides zones.

The assignment of the Young Point beds to the upper portion of the Middle Cambrian is of especial interest. Prior to the recognition of *Paradoxides forchhammeri*, Dr. Matthew on faunal and lithological grounds assigned the Young Point beds to a horizon about in the middle of the Etcheminian. The fauna of the Etcheminian and the Coldbrookian as stated by Dr. Matthew [**2**, p. 72] are very similar. It would appear therefore that in Cape Breton, the oldest known Cambrian is not older than the Middle Cambrian. As far as the evidence presented along the line of section traversed goes, it would appear that the Cambrian is altogether a sedimentary series and that the so-called Coldbrookian is of Pre-Cambrian age.

BIBLIOGRAPHY.

1. Fletcher, Hugh....Geol. Surv. Can., Note on the Sydney Coal Field, Cape Breton. Map-sheets, Nos. 133,134 and 135.

2. Matthew, G. F....Geol. Surv. Can., Cambrian Rocks of Cape Breton, 1903.

ANNOTATED GUIDE.

GEORGE RIVER STATION TO ANTIGONISH.

(G. A. Young.)

Miles and Kilometres.

0 m. 0 km. **George River Station**—Alt. 37 ft. (11·2 m.). From George River station the Intercolonial railway runs eastward around the northern end of the Boisdale hills, and keeping close to the shores of St. Andrew channel, passes along the foot of the western slope of the range of hills. A short distance beyond George River station, the railway enters an area of Cambrian strata which form the western slopes of the hills. The Cambrian beds extend as a comparatively

Miles and Kilometres.

narrow band southeastward throughout the whole length of the Boisdale hills.

At Young point, about 1½ miles (2·4 km.) from George River station, Long island becomes visible from the railway. A small island lying north of Long island is composed of horizontal limestone of the Carboniferous Limestone series. Long island which has a length of about 2½ miles (4 km.), is in part occupied by disturbed sedimentary beds, in part by fine-grained igneous rocks possibly partly extrusive and partly of intrusive origin. The sedimentary strata of Long island are in part at least, of Cambrian age and as described by Matthew, the igneous rocks are of the same age.

Beyond Young point the railway closely follows the shore of the sound separating Long island from the mainland. The bold, eastern rock face of Long island is formed almost entirely of igneous rocks. On the mainland, along the railway are cuttings in dark Cambrian slates and sandstones closely folded along north-south axes. The Cambrian strata extend to the top of the high, steep ridge which rises almost directly from the shore to altitudes of 600 to 700 feet (180 to 215 m.). About opposite the southern end of Long island, the Pre-Cambrian strata which bound the Cambrian on the east, approach closely to the shore and then recede.

5·6 m. 8·9 km. **Barrachois Station.**—Just south of Barrachois station the railway passes through a long cutting in dark slates. These slates are apparently unfossiliferous but on lithological and structural grounds are supposed by Matthew to belong to the Bretonian and to be of Upper Cambrian age. A short distance beyond, the railway crosses the mouth of McLeod brook. The Cambrian measures extend southward up the valley of McLeod brook as a narrow band about ½ mile (0·8 km.) wide and bounded on both sides by Pre-Cambrian rocks. This band of Cambrian strata continues southward across a low divide and thence down the valley of Indian brook almost to the shore of East bay

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which bounds the Boisdale hills on the south. This band of Cambrian strata has a length from the mouth of McLeod brook southward, of about 17 miles (27 km.). In the McLeod brook basin the Cambrian strata apparently belong to the Bretonian (in part lower Ordovician); in the Indian brook basin, all horizons of the Cambrian are represented. Along the eastern side of the band-like area, the Cambrian strata are faulted against the Pre-Cambrian; on the western side, in places at least, the older Cambrian beds rest in an unfaulted condition on the Pre-Cambrian.

After crossing McLeod brook, the railway enters a small irregular area of Carboniferous Conglomerate reposing on Cambrian strata. Beyond this the Cambrian measures continue along the shore for a distance of about 3 miles (4·8 km.) until, opposite a low projecting point, they are succeeded by gently dipping red sandstones and conglomerates of the Carboniferous Conglomerate series. From this point, the Carboniferous measures form an almost continuous band of variable width extending southwestward along the shore of St. Andrew channel. Inland these measures underlie a low, broken country abutting against the steeply rising, high ridges of Pre-Cambrian rocks consisting chiefly of granite associated with relatively limited amounts of "felsite," quartzite, crystalline limestone, etc.

The Carboniferous strata dip in general to the northwest at angles of 10° to 30°. Across St. Andrew channel on Boularderie island, distant about 2¾ miles (4·4 km.), strata of the Limestone series outcrop, dipping in the same general direction beneath the Millstone Grit strata which, in the form of a syncline, occupy the greater part of the island. The Limestone series is characterized by beds of gypsum, white cliffs of which are visible from the railway. Rising above the hills of the island, are high hills [altitude 700 to 900 feet, (215 to 275 m.)] of Pre-Cambrian rocks on the mainland across

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Great Bras d'Or channel on the far side of Boularderie island.

11 m. 17·7 km. **Boisdale Station.**—Near Boisdale station and at intervals beyond, rock cuttings in the red conglomerates and sandstones of the Carboniferous series occur along the railway. The Carboniferous strata continue along the shore for about $5\frac{1}{2}$ miles (8·8 km.) or until about opposite the end of Boularderie island, where sedimentary strata, possibly of Cambrian age outcrop near the shore. From this point to Shenacadie station, several miles further on, the Carboniferous strata are confined to a narrow band, and the front of the high ridges of Pre-Cambrian rocks closely approaches the shore.

19·8 m. 31·8 km. **Shenacadie Station.**— From Shenacadie station onwards to Grand Narrows the railway continues to follow the shore line. Along this stretch the shore is bordered by a narrow strip of strata assigned by Fletcher to the Carboniferous Limestone series. These measures on the inland side are bounded by strata of the Conglomerate series occupying a zone that widens southwards at Grand Narrows to a maximum width of about 3 miles (4·8 km.). The underlying Conglomerate series consists of red conglomerates, sandstones and shales with some bituminous shales, beds of limestone and occasional thin seams of impure coal. The overlying Limestone series contains besides variously coloured sandstones and shales, beds of limestone (in places fossiliferous) and beds of gypsum. Presumably the Limestone series is to be correlated with the Windsor series.

The gypsum does not occur in the narrow strip of the Limestone series traversed by the railway but it is present on the opposite shores of Little Bras d'Or lake. The flat-topped hilly country of the opposite shore is, in part occupied by Pre-Cambrian rocks occurring in two areas but in the main it is occupied by measures of the Conglomerate series lying in a broad anticlinal.

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Along the shore, at intervals, occur patches of the Limestone series which seem to lie along the continuation of the synclinal axes that traverse Boularderie island to the north.

Approaching Grand Narrows, cliff faces in gypsum are visible on the opposite shore.

28·3 m.
45·5 km.

Grand Narrows—At Grand Narrows the railway crosses the strait, about 650 yards (590 m.) wide, connecting Little Bras d'Or lake with Great Bras d'Or lake. These two salt water lakes extend southwesterly through the centre of Cape Breton and almost divide it into two islands. The combined lakes have a length of 60 miles (96 km.) and an area of 360 square miles (935 sq. km.). Long bays, continued inland by low valleys, are a feature of the lakes and these with other characters indicate that the lake basin, in part at least, represents a system of drowned valleys.

After crossing the bridge at Grand Narrows, the railway for a few miles follows the northern shore of Great Bras d'Or lake. Inland rise low hills of the Carboniferous Conglomerate series, while along the shore occurs a comparatively narrow zone of the Limestone series, the strata dipping southerly with angles of 15° to 40°. Cuttings in red conglomerates, shales and gypsum occur along the line of railway for about four miles (6·4 km.), to where the railway line leaves the shore. In a distance of a little over one mile (1·6 km.) the railway again touches the shore at the head of McKinnon harbour, a winding narrow bay about 3 miles (4·8 km.) long.

34·6 m.
55·5 km.

McKinnon Harbour Station—Inland from McKinnon harbour a low, hilly country underlain by gypsum and the associated strata of the Carboniferous series, extends northwesterly for about 4 miles (6·4 km.) to the shores of the St. Patrick channel, a long (25 miles or 40 km.), narrow, irregular bay extending southwesterly from Little Bras d'Or lake. St. Patrick channel is mainly bordered by areas underlain by the Limestone series, but along the northwestern

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shore these areas are narrow and are limited inland by the Carboniferous Conglomerate series or by detached areas of Pre-Cambrian rocks. The Pre-Cambrian strata form bold ridges and hills, in some cases only a couple of miles in diameter, which in some instances rise to heights of 1,000 feet (300 m.). In general, the strata of the Conglomerate series surround the high Pre-Cambrian areas, and in places the Carboniferous strata form uplands comparable in heights with those occupied by the Pre-Cambrian.

Westward from McKinnon Harbour station, the railway at first follows close to the shores of the bay, then leaves the shore for a space, and afterwards again approaches the water; beyond this the railway strikes inland and after a distance of about $1\frac{1}{2}$ miles (2·4 km.) again comes to the shores of the lake towards the head of an inlet which the railway crosses. Along this portion of the railway, cuts and natural exposures of gypsum are visible at intervals, while in other places, the minutely broken and irregular topography suggests that considerable areas are underlain by gypsum. At intervals, views are afforded of the numerous low islands and the inlets occurring in this part of the lake. To the south, across a wide bay studded with islands, may be seen the bold ridge of North Mountain formed of Pre-Cambrian strata rising abruptly to heights of 500 to 700 feet (150 to 215 m.) above the low, encircling Carboniferous areas.

About $4\frac{1}{2}$ miles (7·2 km.) beyond McKinnon Harbour station, the railway as already mentioned, crosses an inlet. This inlet extends inland beyond the railway for about 1 mile (1·6 km.). The head of this inlet is separated from St. Patrick channel by a space of low-lying ground only about 400 yards (360 m.) wide and as the railway crosses the valley of the inlet glimpses are obtainable of the high ridges on the north side of St. Patrick channel. A short distance beyond this, Alba station is reached.

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40·3 m. 64·8 km. **Alba Station**—A short distance beyond Alba, the railway departs from the lake shore to again come upon it after a distance of about 3 miles (4·8 km.) where it passes the heads of several small bays extending inland from North Basin, itself an arm of an irregularly shaped inlet known as Denys basin. At various points as the railway passes within sight of North basin, the steeply rising north end and northwest flank o the ridge of North Mountain is visible. At Orangedale station, the railway passes around the head of North basin and looking up the valley at the head of the basin, the high ridge of Craignish hills, about 5 miles (8 km.) distant, may be seen rising from the Carboniferous lowland. All of the low country, 7 to 9 miles (11·2 to 14·5 km.) broad, between the Craignish hills on the northwest and North Mountain on the southeast, is occupied by the gypsum, limestone and associated strata of the Carboniferous Limestone series.

45·4 m. 73·0 km. **Orangedale Station**—About 1½ miles (2·4 km.) beyond Orangedale station the railway skirts the head of Seal cove, the last point on the railway from which the waters of Bras d'Or lake are visible. Beyond Seal cove, the railway passes into the valley of River Denys, a winding sluggish stream. The railway follows the river for some distance, then crosses it, and 2 miles (3·2 km.) beyond passes River Denys station.

Between Orangedale and River Denys, the railway gradually approaches North Mountain and a number of uninterrupted views are afforded of the steep northwest face rising from the low-lying area underlain by the Limestone series. The ridge of North Mountain rises to heights of between 600 and 800 feet (180 to 240 m.) and is formed of Pre-Cambrian rocks. A portion of the Pre-Cambrian is composed of crystalline limestone, quartzite and various types of schists associated with "felsites". Such rocks occur

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in detached areas but the bulk of the Pre-Cambrian is formed of granite and which is intrusive into the limestone, etc.

53·3 m.
85·7 km.
River Denys Station—Alt. 72 ft. (21·9 m.). From River Denys station the railway runs southwestward up the valley of Big brook along the foot of the slope of North Mountain. The valley of Big brook is underlain by strata of the Limestone series dipping at angles of 20° to 70° to the west beneath a synclinal basin of Millstone Grit and perhaps younger strata lying about midway between the Pre-Cambrian areas of North Mountain on the east and the Craignish hills on the west. In the lower part of the valley of Big brook, the Craignish hills, distant 6 to 8 miles (9 to 13 km.), are visible but as the railway ascends the valley the view of these hills is cut off by the intervening ridge of Millstone Grit. Towards the head of Big brook valley, the bounding ridge of younger Carboniferous strata on the west attains altitudes comparable with those of North Mountain along the foot of which the railway continues to run.

From the head of Big brook valley the railway crosses a summit (altitude, 286 feet or 87·2 m.) and enters a watershed draining southward to the Strait of Canso. As the railway descends, a view is afforded to the westward across the wide low valley of River Inhabitants which flows from the northwest. The valley of the river and the lower slopes on both sides are underlain by strata of the Limestone series and perhaps older divisions of the Carboniferous dipping in various directions and traversed by a series of east-west and north-south faults. The higher lands on the western side of the valley are occupied by measures that have been mapped as Devonian but which are believed to include at least some members that are the equivalent of the Horton series (Lower Carboniferous). The areas of so-called Devonian encircle or partly surround still higher ridges of Pre-Cambrian strata.

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60·6 m. 97·5 km. **West Bay Road Station**—Alt. 214 ft. (65·2 m.). West Bay Road station is situated at the southern end of the Pre-Cambrian area of North Mountain. Beyond this station, as the railway descends to the crossing of River Inhabitants, the higher ground on the east is occupied by Millstone Grit. Where the railway crosses the river, the waters are practically at sea level. Beyond the river crossing the railway ascends the long slope on the southwestern side of the river valley underlain by the Limestone series and passes along the eastern side of two small lakes. About 1½ miles (2·4 km.) beyond the second of the two lakes the railway enters an area occupied by Millstone Grit and in part by strata belonging to the Coal Measures. From this point onwards the railway descends to Point Tupper on Canso strait. As the descent is made an extensive view is afforded of the upland country of the mainland across the straits. This upland area is chiefly underlain by strata mapped as Devonian and which are in part at least the equivalents of the Riversdale-Union series. A high, isolated hill known as Cape Porcupine rising on the western side of the straits, is occupied by Pre-Cambrian strata. As the railway nears the shore, rock cuttings in variously coloured shales and sandstones are common.

The Carboniferous area traversed by the railway from the River Inhabitants valley to Point Tupper includes a series of strata having a thickness of at least 19,000 feet (5,800 m.). The strata are traversed by strong faults and doubtless many minor faults are also present. The measures are usually inclined at rather high angles and apparently lie in open folds of large dimensions. Both on the west and east occur large areas of so-called Devonian. Sandstones and dark shale that have been correlated with the Horton series occur at the base of the measures that have been definitely assigned to the

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Carboniferous. Above these lie limestone and gypsum beds followed by a great thickness of shales and reddish and grey, plant-bearing sandstones. Above these lies a thick series of black shales with, in several places, coal seams. The highest strata presumably belong to the Coal Measures.

74·5 m. 120 km. **Point Tupper**—From Point Tupper the railway trains are ferried across Canso strait to the terminus of the railway on the mainland at Mulgrave . The strait at this point is 1,400 yards (1,280 m.) wide.

Along the shore on the Cape Breton side of the strait, the strata dip easterly at angles of 30° to 60°, and are well exposed over many partial sections to the north and south of Point Tupper.

From the Cape Breton side of the strait, the mainland is seen to rise quickly to a rolling upland. To the north however, the Pre-Cambrian area of Cape Porcupine forms a detached, higher mass. Nearly the whole length of the mainland side of the strait is bordered by so-called Devonian strata which extend from here in a continuous band westward to Windsor. These "Devonian" measures are of variously coloured shales and sandstones with an aggregate thickness of, presumably, considerably more than 5,000 feet (1,500 m.). The strata dip in various directions at angles usually of 45° or higher; they apparently are much folded. Plant-bearing beds occur at various horizons and, in a general way, the measures have been correlated with the Riversdale-Union group. At several places strata of the Horton series occur within this area in the neighborhood of Canso strait, and at several places along the shore, as just south of Mulgrave, there are limited areas of the Carboniferous Limestone series.

75·2 m. 121·1 km. **Mulgrave**—After leaving Mulgrave on the mainland side of Canso strait, the railway enters the valley bounding Cape Porcupine hill on the south and west. From this point may be seen the rolling ridges and low rounded summits of

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the Carboniferous area stretching inland from Point Tupper on Cape Breton island.

The railway passes close to the steep west face of Cape Porcupine hill which rises to an elevation of 640 feet (205 m.). This hill with a maximum diameter of $1\frac{1}{2}$ miles (2·4 km.) is the only area of older Pre-Cambrian on the mainland of Nova Scotia. The rocks of the hill consist of quartzite, schists, "felsite," granite, etc. After passing to the west of Cape Porcupine, high hills and ridges on Cape Breton island are visible. These uplands lie in the Pre-Cambrian and "Devonian" area situated to the west of the Carboniferous area of the River Inhabitants basin.

After passing Cape Porcupine hill, the railway rises to a summit elevation of 398 feet (121·3 m.) and beyond this begins to drop to a lowland Carboniferous area that extends along the coast westward from the northern entrance of Canso strait. For about 3 miles (4·8 km.) westward, the railway continues through a somewhat broken country underlain by the "Devonian" strata. Beyond this the railway begins to descend somewhat rapidly and enters a district underlain by the Carboniferous Conglomerate series. This series consits of coarse red conglomerate and sandstone, purple slates, etc. Included in the area are dark shales, sandstones and thin limestones of the Horton series. The strata in a general way dip to the west away from the "Devonian" area and towards the coast, where, a few miles away, overlying beds of the Limestone series occur.

85·3 m.
137·3 km.
Harbour au Bouche Station—Alt. 271 ft. (82·6 m.). After passing Harbour au Bouche station, a view is afforded to the north of the hills of Pre-Cambrian rocks, in Cape Breton. To the west an extensive view opens up of the low-lying Carboniferous area bordering the sea as far as Antigonish, of the ranges of hills beyond Antigonish limiting the Carboniferous area in that direction, and of the upland of

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"Devonian" strata bounding the Carboniferous on the south.

Approaching Linwood, heavy cuttings in conglomerate, sandstone and shale occur along the railway. The rocks belong to the Conglomerate series and dip to the west at angles of 15° to 40 °.

89·3 m. **Linwood Station**—Alt. 127 ft. (38·7 m.).
143·7 km. From the railway to the west of Linwood, the steep front of the ridges of "Devonian" may be plainly seen rising a short distance to the south. About $2\frac{1}{2}$ miles (4 km.) beyond Linwood near the bridge over Black river, the railway line crosses the boundary between the Conglomerate series on the east and the Limestone series on the west. The Limestone series consists chiefly of sandstones and shales of various colours and kinds and in places bearing plant remains, and beds of limestone and gypsum. These measures, directly border the "Devonian" area on the south. The measures, in places over considerable areas, apparently lie in broad, open folds, in other districts the folding is closer and in certain areas the strata are contorted.

Less than 1 mile (1·6 km.) beyond the crossing of Black river, the railway approaches the shore of Tracadie harbour and continues to skirt it for a distance of several miles.

94 m. **Tracadie Station.**—Alt. 48 ft. (14·6 m.).
151·3 km. A short distance beyond Tracadie, the railway leaves the coast and for a number of miles runs through a low rolling country underlain by the Limestone series. The high lands to the west beyond Antigonish, continue in view throughout most of the distance. About 9 mile (14·5 km.) from Tracadie, the railway passes around the head of Pomquet harbour, an inlet of the sea about 3 miles (4·8 km.) long.

104·1 m. **Pomquet Station.**—Alt. 43 ft. (13·1 m.).
167·5 km. From Pomquet, the railway again strikes inland through the low Carboniferous area.

108·9 m. **South River Station.**—Alt. 20 ft. (6·1 m.).
175·2 km. A short distance beyond South River station, the railway approaches the shore of Antigonish

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harbour, an inlet of about 5 miles (8 km.) in length. The railway follows the shore of Antigonish harbour around a point and thence inland along the east side of the estuary of West river. Across the estuary on the northeast side, beyond a low interval occupied by the Limestone series, rise comparatively high hills of igneous material and Ordovician strata. Beyond these to the northward, the upland rises to altitudes of 600 feet (180 m.) and more, and is largely occupied by strata of the Carboniferous Conglomerate series. The upland area also extends inland and from the mouth of West river the hills to the west are distinctly visible. The railway runs inland along West river and in a short distance reaches Antigonish. The town is situated within but close to the northern border of the Limestone series which a mile to the north abuts against the hills of older strata.

114 m. 183·5 km. **Antigonish** —Alt. 20 ft. (6·1 m.).

ARISAIG.*

(W. H. Twenhofel.)

INTRODUCTION.

The Arisaig region consists of an upland built of old metamorphic and igneous rocks, having an average elevation of 800 to 1,000 feet (243 m. to 304 m.) and a lowland underlain by softer and younger sediments with an elevation of from 200 to 400 feet (60·9 to 121·9 m.). Nestling in the midst of the uplands are small lakes and wide marshes in which the brooks take their sources and, fed by never failing mountain springs, rarely cease their flow. The streams of the upland flow in deeply incised gorges and reach the lowland by a succession of falls and rapids, where they meander in gently graded valleys to the sea. On the top of the upland, the flat fields prove the former presence of an extensive, nearly level surface.

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*See Maps—Arisaig—Antigonish District, and Arisaig.

Geological Survey, Canada.

Arisaig-Antigonish District

Miles

Kilometres

Viewed from the sea, the lowland presents the appearance of three gigantic steps. The highest step at an elevation of about 140 feet (42 m.) is not well preserved; but the lowest two, at elevations of 20 (6 m.) and 40 feet (12 m.), are sharply defined. Each represents a wave cut beach.

For splendid exposures of Silurian rocks of great thickness there are few regions which surpass that of Arisaig. The shore cliffs are well developed and these with the sections exposed in the brook gorges show the Arisaig region to consist of large blocks, bounded by faults of great magnitude, so that a structural and formational map of the region forms an irregular mosaic. The fault of greatest displacement is that separating Eigg mountain from the narrower block of Silurian hills which fronts it. On the land the locus of the fault zone is plainly shown by the pronounced structural depression known as the Hollow which can be followed westward to Bailey's brook while its northeastward extension forms the straight coast reaching nearly to the end of the peninsula of Cape George. The downthrow of the Silurian block proved its preservation, but in its descent the drag along the fault zone produced an asymmetric synclinal trough, the rocks of which are criss-crossed by myriads of small faults and fractures.

PREVIOUS WORK.

The first student of the Arisaig sequence was J. W. Dawson, who investigated the region previous to 1845. He was succeeded by David Honeyman, who began his studies there about 1859. Following Honeyman came Fletcher, Faribault, Ami, Schuchert, Twenhofel, and Williams; each of whom has studied the section in whole or in part and in their published results have built up our present knowledge of the region. A compilation of their results is summarized in the following table of formations.

TABLE OF FORMATIONS.

System.	Formation.	Thickness.	Lithology.	Correlation, U. S.	Correlation, Europe.
Pennsylvanian.	Listmore.....	(Feet.) 982	Grey and brown sandstone and shale of continental origin.		
Mississippian.	Ardness......	2,045	Varicolored shale and sandstone with locally some beds of gypsum and a basal limestone.	Kinderhook.	
	McAra's Brook...	1,145	Varicoloured shale and red sandstone and conglomerate with dykes and sheets of diabase.		
Lower Devonian.	Knoydart....	683+	Red sandy shale and grey sandstone with small dykes of diabase.	....	Old Red Sandstone.
Silurian	Stonehouse ..	1,075	Red and grey limestone and shale.	Guelph...........	Ludlow.
	Moydart.....	379	The "Red Stratum" and grey limestone and shale.	Waldron and Louisville.	Upper Wenlock.

Silurian	McAdam....	1,120	Black and grey shale, grey limestone and 27 in. of hematite.	Rochester..........	Upper Wenlock. Upper Llandovery.
	Ross Brook..	833+	Green and black shale with interstratified thin sandstone.	Clinton............	Lower Llandovery.
	Beech Hill Cove.	160+	Sandy limestone and shale underlain by a rhyolite flow into which have been intrusions of diabase.	Lowest Clinton.	
Ordovician?	Malignant Cove.	20+	Cross-bedded conglomerate with dykes of basalt.		
Ordovician?	Baxter's Brook.	500+	Red and grey sandstone and slate with intrusives of rhyolite, quartz porphyry, diabase and basalt.		
	James River.	5,280+	Flinty slate and grit with intrusives of granite, rhyolite, diabase, basalt, and monzonite.		

Antigonish to McAra's brook.

The town of Antigonish (alt. 40 ft., 12 m.) is situated in the valley of Right river which follows what is apparently an ancient depression, now partially filled with the Carboniferous rocks of the McAra's Brook and Ardness formations, the latter of which immediately underlies the town. Less than a mile to the north of Antigonish the surface rises rapidly to the plateau, here underlain by the James River rocks, through which protrudes a core of diabase forming the elevation known as Sugar Loaf hill (alt. 760 ft., 213 m.). This portion of the plateau is separated from the larger area to the west by a lowland whose surface rocks belong to the McAra's Brook formation and through this lowland the Gulf road follows the valleys of Right river and Malignant brook to Malignant cove. Outcrops are not common. About two miles south of the Malignant cove shore the quartz porphyry of McNeil's mountain rises to the west of the road to an elevation of 1,010 feet (307 m.) while about a mile north the rhyolite hill of Sugar Loaf ascends to 680 feet (207 m.). At Malignant cove, a conglomerate, probably of Ordovician age forms the surface rock and may be seen at the Malignant Brook bridge crossing. For the first half mile west of Malignant cove the road is underlain by this conglomerate after which the Silurian forms the surface rock to McAra's brook.

McAra's brook and the shore section east to Arisaig point.

Just above the bridge crossing at McAra's brook are splendid exposures of the sandy shales from which Ami obtained his Old Red Sandstone (Knoydart) fossils. Below the bridge the hard red shales and grey sandstones are exposed in the bed and along the bank. A road along the west bank of the brook leads to its mouth, where the shore cliffs are formed either of the McAra's Brook conglomerate or the diabase intrusives by which it is cut. about a mile to the west the rocks of the Ardness formation form the cliffs, while the farthest headland visible from this point is in part built of the Pennsylvanian? conglomerates. McAra's brook reaches the sea by a gateway cut through a diabase dyke, on the seaward side of which

some blocks of the Mississippian conglomerate have been included in the diabase. By ascending the brook the Devonian shales as well as the Mississippian conglomerate and the amygdaloid which lies just above the base of the latter may be seen. For the first 250 yards (228 m.) east of McAra's brook the shore is formed almost wholly of amygdaloid. There is no beach and the top of the cliff must be followed. At McAra's boat landing, where descent can be made to the beach, the amygdaloid is succeeded by the McAra's Brook conglomerate which then forms the shore for about 125 yards (114 m.) where it is succeeded by the diabase dyke at the top of the Silurian. It is quite easy here to make a representative collection of fossils from the Silurian red limestones and shales. At the mouth of Stonehouse brook it is possible to obtain entire specimens of the trilobite, *Homalonotus dawsoni*.

From Stonehouse brook to beyond the "Red Stratum" there is no beach and this portion of the Silurian section must be studied from the top of the cliff. The "Red Stratum" and the overlying green shales are without fossils, but the limestone which underlies the former and forms the point to its east contains many specimens of a brachiopod resembling *Eatonia medialis*. Beyond this point is McDonald Brook cove wherein the Moydart rocks form low cliffs. The succeeding point is also formed of Moydart rocks, but in the cove to the east the formation comes to an end. At the western end of this cove descent can be made to the beach which, with few interruptions, extends to Arisaig point. The upper beds of the McAdam formation form a serrated cliff from which it is quite easy to collect many fossils, of which few are well preserved. The point east of McAdam Brook cove is formed of shales, which are full of pelecypod casts, and nearly unfossiliferous limestone. The eastern side of the succeeding cove does not offer good exposures, but from a few interstratified beds of limestone which project through the beach debris it is possible to collect large individuals of *Atrypa reticularis*. The slopes above this cove show the elevated terraces in a fine state of preservation. At its eastern horn is Black point, a headland formed of glacial gravels, on the eastern side of which the McAdam formation ends, being cut off by the fault which has elevated the Ross Brook shales and placed them on a level

with the basal McAdam limestones here forming a low anticlinal. At low tide the fault line is well shown, the shales on one side and the limestones on the other serving to make it very prominent, but at high tide it can not be seen. Beginning at the fault is the broad cove extending to Arisaig point. Its existence is determined by the readiness with which the Ross Brook shales yield to erosion. The upper half of the exposures is made prominent by the high cliffs of green shales, but in the lower half the cliffs are less high and steep. The lenticular beds of sandstone which are scattered through the shales make disconnected shelves across the cliffs and their varying thickness is excellently shown. In the green shales it is possible to collect fossils anywhere, but perfect specimens do not commonly occur. A good black shale fossil locality begins about 125 yards (114 m.) west of the mouth of Arisaig brook and extends to its east bank.

Arisaig point is formed of the upturned edge of the rhyolite flow at the base of the Silurian which, together with the amygdaloid by which it has been intruded, forms with a few interruptions, the shore for the next three miles.

The Beach Hill cove formation is so poorly exposed at Arisaig point that it is not possible to adequately examine it To see it in its completeness Beech Hill cove or Doctor's brook must be visited. The former locality is about three miles east of Arisaig point and is best reached by way of the shore road. There the beds are steeply upturned and form a sloping shore which at no place rises to a cliff. At Doctor's brook the beds of the Beech Hill cove formation form the cliffs below the shore road bridge and the same structural relations obtain as at Beach Hill cove.

DESCRIPTION OF THE GEOLOGICAL SEQUENCE.

The sequence of the strata in the Arisaig region begins in the Lower Ordovician and with many interruptions extends perhaps to the Pennsylvanian. Excepting the glacial and stream gravels there are no deposits later than the Pennsylvanian.

Ordovician, Brown's Mountain Group.

The oldest rocks of the region have been described as the Brown's Mountain group, a name proposed by Willliams. On lithological grounds the group has been divided

into two formations, the lower and thicker of which is called the James River, and the upper, the Baxter's Brook. The strata lie in broad open folds on which have been superposed smaller secondary folds.

James River Formation.—The James River formation is described by Fletcher and Williams as consisting of clastic deposits of graywacke, silicified grits and banded slates into which have been intruded rocks of such varied character as granite, monzonite, rhyolite, quartz porphyry, diabase and basalt. The thickness according to Williams approximates one mile. Areally the rocks of this formation constitute the greater portion of the plateau and they contain most of "the beds" of iron ore which have been prospected here for many years. Some of the ore "beds" of the upper parts are similar to those of the Belle Isle oölitic deposits of Conception bay, Newfoundland, while other "beds" in the formation consist of grit impregnated with hematite. Williams inclines to the belief that the ores are of sedimentary origin. Their economic importance and extent are yet to be determined. From the iron ore and associated beds have been collected two species of inarticulate brachiopods, determined by Schuchert as *Obolus* (*Lingulobolus*) *spissa* and *Lingulella?*

Baxter's Brook Formation.—The James River rocks are succeeded on the northern portion of the plateau by the Baxter's Brook formation, consisting of metamorphosed red and grey sandstones and slates. Like the rocks of the preceding formation these have been cut by similar or the same intrusives with the exception of monzonite. The only fossils so far found are indeterminable *Linguloids*. Williams estimates the present thickness at 500 feet which is probably far less than the original.

Ordovician?

Malignant Cove Formation.—At Malignant Cove are exposed about 20 feet of coarse cross-bedded conglomerates and sands of varied color which rest unconformably on cleavage surfaces of the James River slates. These clastics contain material derived from all the preceding sedimentaries and intrusives except the diabase and basalt.

The deposits are probably not of marine origin, this conclusion being based on the absence of marine fossils and the poorly bedded and little sorted character of the sediments.

Silurian. Arisaig Series.

Where the base of the Silurian has been seen it rests on the eroded surface of a rhyolite flow extruded before the marine overlap of Arisaig time. The fault of the Hollow separates the Silurian from the Ordovician. On lithological grounds the strata can be placed in two subdivisions; the lower portion consisting almost entirely of shales, has a thickness exceeding 2000 feet (510 m.) while the upper shales and impure limestones are 1454 feet (373 m.) thick. The character of the sediments denotes proximity to the shore, a conclusion confirmed by the pronounced development of ripple marks, cross-lamination, and small lenses of sandy and impure limestone. On the basis of lithology and faunal differences the Arisaig series can be divided into five well marked formations to which, beginning at the base, the names of Beech Hill Cove, Ross Brook, McAdam, Moydart, and Stonehouse have been applied.

Beech Hill Cove formation.—This formation consists of greenish calcareous sandstones, sandy impure limestones and grey sandy shales. At the type section and at Doctor's brook the strata have an almost vertical attitude. The formation is poorly exposed at Arisaig point. Along the line of the Intercolonial railroad on Barney's river, opposite the mouth of Bear brook, and again at Marshy Hope, are outcrops of strata which probably belong to this formation. Fossils are nowhere abundant but the following have been recognized: *Zaphrentis* cf. *bilateralis*, *Lingula* cf. *oblonga*; *Dalmanella* cf. *elegantula*, and *Cornulites flexuosus*. The thickness has never been accurately determined. The present writer estimated the Beech Hill Cove outcrop at 160 feet (48 m.) while Williams gives the thickness as 200 feet (61 m.).

Ross Brook formation.—The strata of the Ross Brook are divisible into two divisions, a lower one (zone 1) of black papery shales with a thickness of about 200 feet (61 m.) from which no graptolites have been collected, and an upper division, 633 feet (193 m.) thick, throughout which graptolites are present in abundance. The upper division is again readily divisible into a lower subdivision

of dark grey to black shales (zone 2) with either splintery or papery cleavage and an upper one (zone 3) of more or less sandy bright green shales with which are interstratified numerous lenticular beds of compact, finely cross-laminated quartz sandstone. What appears to be the basal portion of the Ross Brook formation also outcrops on Barney's river opposite Avondale station on the Intercolonial railroad, where beds lithologically and faunally similar but without any graptolites form a cliff about 30 feet high on the north bank of the river.

The fossils which are characteristic of the formation are:

Monograptus clintonensis
M. priodon chapmanensis
Retiolites geinitzianus venosus
Orbiculoidea tenuilamellata
Dalmanella elegantula
Leptaena rhomboidalis
Plectambonites transversalis
Chonetes tenuistriatus
Camarotoechia near equiradiata
C. *cf.* obtusiplicata
Rhynchonella *cf.* robusta
Anoplotheca hemispherica
Anabaia anticostiana
A. depressa; and Calymene tuberculata.

Zone 1.—Black, rusty weathering papery shales which as a rule are little fossiliferous. The identified fossils are *Anoplotheca hemispherica; Anabaia anticostiana;* and *Lingula* cf. *oblongo;* The estimated thickness is 200 feet (61 m.).

Zone 2.—Dark-grey to black, rusty weathering shales with splintery or papery cleavage. In the shore cliffs the zone shows much disturbance and in some places the attitude changes with nearly every ten-foot interval. It is quite fossiliferous, particularly in graptolites, while pelecypods and brachiopods are comparatively common throughout and at a few levels are very abundant. The identified fossils are:—

Monograptus clintonensis
M. priodon chapmanensis
Retiolites geinitzianus venosus
Orbiculoidea tenuilamellata
Dalmanella elegantula
Chonetes tenuistriatus
Anoplotheca hemispherica

Anabaia anticostiana
A. depressa
Cornulites flexuosus
C. distans
Calymene tuberculata
Acaste downingiae
Dalmanites *sp.*

The thickness is 288 feet (87 m.).

Zone 3.—Green shales, in places sandy. Interbedded are numerous layers and lenses of fine-grained sandstones with fine cross-lamination. The strata are much disturbed in places, but the units of fracture are much larger than in the preceding zone so that there are few places where the bedding is confused. The zone ends at the top of the formation. The fossils which have been identified are:—

Monograptus clintonensis
M. priodon chapmanensis
Retiolites geinitzianus venosus
Orbiculoidea tenuilamellata
Dalmanella elegantula
Leptaena rhomboidalis
Chonetes tenuistriatus
Camarotoechia near equiradiata
C. cf. obtusiplicata
Rhynchonella cf. robusta
Wilsonia cf. saffordi
Anoplotheca hemispherica
Serpulites cf. dissolutus
Cornulites distans
Pterinea emacerata
P. rhomboidea
P. honeymani
Modiolopsis? cf. primigenis
Dalmanites, fragments of Eurypterus, and Conularia.

The thickness of the zone is 365 feet (110 m.)

McAdam formation.—The strata of this formation consist of papery and splintery shales, and argillaceous and sandy limestones. The attitude is more regular and uniform than in the preceding formation and there are fewer zones of marked disturbances. In the shore cliffs the lower portion is cut out by faulting, but the missing strata can be well seen in the gorge of Arisaig brook. The formation has been separated from the Ross Brook formation on both lithological and faunal grounds though

many species are common to both. The fossils which are especially characteristic are *Monograptus* cf. *riccartoensis*. *Dalmanella elegantula, Leptaena rhomboidalis, Camarotoechia neglecta, Atrypa reticularis, Spirifer crispus, Bucanella trilobata* and *Calymene tuberculata*. The McAdam formation has a thickness of 1120 feet (366 m.).

Zone 1.—The iron ore zone. Williams has described this zone as consisting of "firm shales and thin-bedded sandstones with 2 feet 3 inches of ferruginous shale and weathered hematite." The hematite is a "fossil ore" similar to the Clinton ore of the Appalachian region. The fossils are *Dalmanella elegantula, Leptaena rhomboidalis, Camarotoechia* near *neglecta, Homeospira* sp., *Meristina* near *oblata,* and *Cornulites flexuosus* or *proprius*. Since the fauna does not contain *Monograptus clintonensis* or *Anoplotheca hemispherica* and is more closely related to that which follows than that which precedes it has been referred to the McAdam formation. The thickness has been estimated by Williams at 100 feet (30 m.).

Zone 2.—Grey and greenish impure limestones interstratified with shale of the same color. The zone ends at the mouth of McAdam's brook. The identified fossils are:—*Pholidops implicata, Dalmanalla elegantula, D.* (a very large new species), *Leptaena rhomboidalis, Camarotoechia neglecta, C.* cf. *obtusiplicata, Atypra reticularis, Pterinea emacerata, Tentaculites* sp. and *Homalonotus dawsoni*.

The thickness is 540 feet (165 m.).

Zone 3..—Dark grey to black carbonaceous shale, the greater portion with papery bedding cleavage. At several levels are lenticular beds of fine-grained cross-laminated sandstone. The fossils are:—

Dalmanella elegantula
Laptaena rhomboidalis
Chonetes tenuistriatus
Camarotoechia neglecta
C. obtusiplicata
Atrypa reticularis
Spirifer crispus
Grammysia sp.
Cleidophorus sp.
Bucaniella trilobata
Calymene tuberculata.

About 75 feet (22 m.) from the top is a layer about one inch thick in which *Monograptus* cf. *riccartoensis* is present

in great abundance, while about 25 to 50 feet lower down there are many very large oblate spheroidal concretions. This zone has a thickness of 405 feet (123 m.).

Zone 4.—Grey and greenish grey impure limestones in thick layers all of which are steeply upturned with many of the beds beautifully ripple marked. Near the top they are much disturbed and in some places the bedding has been destroyed and the rocks reduced to breccia. *Dalmanella elegantula*, *Chonetes tenuistriatus* and *Cleidophorus* have been recognized. The estimated thickness of this zone is 70 feet (21 m.).

Moydart formation.—This formation introduces a change in lithology, the dark shales giving way to impure limestones and shales of some shade of grey. The change in facies is paralleled by a change in fauna. The formation ends on the top of the "Red Stratum."

The fauna is especially characterized by the appearance of *Chonetes novascoticus* and *Spirifer subsulcatus*, these two species taking the places of the earlier *Chonetes tenuistriatus* and *Spirifer crispus*. Other characteristic species are *Camarotoechia* cf. *formosa*, a rhynchonelloid resembling *Eatonia medialis*, *Homeospira* cf. *acadica*, *H.* cf. *evax*, *Pterinea emacerata*, *Grammysia* cf. *acadica*, *Diaphorostoma niagarensis*, and *Homalonotus dawsoni*. The thickness is 379 feet (115 m.).

Zone 1.—Greenish grey, impure limestone in beds up to four feet in thickness, interstratified with blue and grey sandy shales. As a rule fossils are not common, but in some limestone lenses they are present in great abundance. They consist of large crinoid columns, thick stems of a branching *Monticuliporoid*, *Dalmanella elegantula*, *Camarotoechia* cf. *formosa*, a rhynchonelloid resembling *Eatonia medialis*, *Spirifer subsulcatus*, *Homeospira* cf. *acadica*, *H.* cf. *evax*, *Pterinea emacerata*, *Grammysia acadica*, *Cornulites proprius*, *Serpulites* cf. *dissolutus*, *Orthoceras* (two species), *Diaphorostoma* cf. *niagarensis*, *Calymene tuberculata*, and *Homalonotus dawsoni*. The zone ends at the base of the "Red Stratum," and has a thickness of 347 feet (105 m.).

Zone 2.—The "Red Stratum," consists of a brick red shale of which the major portion has prismatic structure. Little stratification is shown except near the base where 27 inches of thin beds of red limestone and shale are transitional to the zone below. There is no transition to the overlying green shale. About 20 feet (6 m.) below the

top is a band composed of bright green nodules with their longer axes transverse to the bedding with a thickness of about 10 inches. Fracture lines which cut the "Red Stratum" are sharply defined by streaks of brilliant green. Except for some obscure forms in the transition beds at the base the zone is without fossils. The absence of well defined bedding and marine fossils suggests that the "Red Stratum" is not typically marine and that its deposition may have taken place during a brief recession of the sea. The thickness is 32 feet (9 m.).

Stonehouse formation.—This, the closing formation of the Arisaig series, is by far the most fossiliferous of the sequence. Lithologically the first 800 feet (243 m.) are not very different from the limestones of the Moydart formation, but faunally there is quite a distinction, the difference being largely in the abundance of large and undescribed pelecypoda. An unknown thickness of what appears to be the lower portion of the formation outcrops on the southwest end of a hill near the head of Vamey brook. The beds at this locality are flanked on both sides by the Devonian red shales and the structure appears to be anticlinal. The fauna is a large one and is characterized by the abundance and large size of *Chonetes novascoticus*, and an abundance of *Pholidops implicata*, *Spirifer rugaecosta*, *Homeospira* n. sp., *Grammysia acadica*, *G. rustica*, *Pterinitella venusta*, *P. curta*, *Calymene tuberculata*, *Acaste logani*, and fine large specimens of *Homalonotus dawsoni*,and in the last 200 feet (60 m.) by myriads of *Beyrichia pustulosa* and *B. aequilatera*. There is a total thickness of 1,075 feet (327 m.).

Zone 1.—Deep green unfossiliferous shales with a few lenticular bands of limestone. The zone rests in apparent conformity on the "Red Stratum", but the contact is obscure. The thickness is 33 feet (10 m.).

Zone 2.—Grey to green impure limestone in thick beds with a few beds of green and rusty purple shales and blue splintery flags. The limestones are criss-crossed by seams of quartz and calcite and the surfaces of many of the beds are highly ripple marked. The zone ends at the mouth of McPherson's brook. Fossils are not uncommon, but at no place are they abundant. They are *Stropheodonta* n. sp., *Leptaena rhomboidalis*, *Chonetes novascoticus*, *Atrypa reticularis*, *Spirifer subsulcatus*, *S. rugaecosta*, *Homeospira* cf. *evax*, *Grammysia acadica*, and *Pterinitella venusta*. The thickness is 532 feet (162 m.).

Zone 3.—Red and green shales, red and grey impure limestones, and grey splintery flags. The hard beds are veined by quartz and calcite and ripple marked as in the preceding zone. The zone ends at the mouth of Stonehouse brook and is very fossiliferous. The identified fossils are:—

Pholidops implicata
Chonetes novascoticus
Camarotoechia cf. nucula
C. cf. borealis
Spirifer rugaecosta
Homeospira n. sp.
Cornulites proprius
Beyrichia aequilatera
B. pustulosa
Acaste logani
Calymene tuberculata
Homalonotus dawsoni
Pterygotus fragments.

The zone has a thickness of 136 feet (41 m.).

Zone 4.—Red shales and limestones with greyish blue splintery flags. In the cliffs of the shore section this zone is spotted with very bright green patches. The base is drawn beneath the six inch layer of limestone forming the bed of Stonehouse Brook at its mouth and which contains an abundance of *Homalonotus dawsoni*. The zone is very fossiliferous. Those specifically known are:—

Pholidops implicata
Chonetes novascoticus
Schuchertella pecten
Camarotoechia cf. nucula
Spirifer rugaecosta
Homeospira n. sp.
Pterinitella venusta
Bucanella trilobata
Grammysia acadica
Goniophora transiens
Cornulites proprius
Beyrichia pustulosa
B. aequilatera
Calymene tuberculata
Acaste logani
Homalonotus dawsoni

The thickness is 97 feet (29 m.).

The section ends here, abutting against a dyke of diabase, the intrusion having flexed the beds, but little altered them. The dyke has a thickness of 40 to 50 feet (12 to 15 m.) and on its opposite side is in contact with the McAra's Brook conglomerate, the bedding of which is tilted in the same general direction as that of the Stonehouse formation, but there is no apparent alteration of the rock.

Devonian.

Knoydart formation.—The strata of this formation lie in the syncline formed by the Silurian rocks. An erosion unconformity separates the formation from the Silurian, since at McAra's brook it rests on the Stonehouse formation and in McAdam brook on the Moydart (Williams). It does not appear in the shore section, probably having been eroded before the deposition of the Mississippian conglomerates. The strata consist of hard red shales interbedded with compact fine-grained grey sandstones. Above the bridge over McAra's brook are sandy shales which were formerly considered to be of tuffaceous origin and have been referred to in the literature as the "ash bed," but the work of Williams has thrown doubt on this view. Several diabase dykes occur in the lower portion and in the higher rocks of the formation there are numerous small geodes lined with clear crystals of quartz. The available evidence indicates a continental origin for the Devonian sediments and it is very probable that they are the deposits of some Devonian river. From the "ash bed" Ami collected fossils which were identified by A. Smith Woodward and Henry Woodward as *Pterygotus* sp., *Onchus murchisoni*, *Pteraspis* cf. *crouchii*, *Psammosteus* cf. *anglicus*, *Cephalaspis* n. sp., and *Ichthyordichnites acadiensis*, the last being impressions made by a supposed animal having sharp pointed spines or similar organs. Fletcher (1887) gives the thickness of measured outcrops as 636 feet (193 m.).

Mississippian.

McAra's Brook formation (Williams).—This formation begins with a red cross-bedded conglomerate composed of angular fragments of the older rocks, in particular some of the quartz geodes from the Devonian. Above

the basal conglomerates are beds of limy grey and green shales and other conglomerates. Many intrusive bodies, in the form of dykes and sheets, cut the formation. At Pleasant valley and in the vicinity of Maryvale in the Big Marsh, the upper portion contains beds of oil shale (Ells, 1908), which with associated beds have a thickness of 125 feet (38 m.). Plant fragments are present in these shales, but in the shore sections no organic remains have been found. There is hardly any doubt that the deposits are of continental origin and were laid down in the old erosion channels. Fletcher gives the thickness as 1145 feet (346 m.).

Ardness formation.—This formation begins with about 20 feet (6 m.) of limestone, thin-bedded at the summit and base, but compact near the centre. The remaining more than 2000 feet (610 m.) consist of sandstone, shale and marl. The prevailing color is red and the sandstones are ripple marked. Along the line of the Intercolonial railroad near Antigonish the bed of limestone is overlain by about 200 feet (60 m.) of red sandstone and shale which are followed by about an equal thickness of gypsum. The bed of limestone is certainly of marine origin while the gypsum was probably deposited in arms of the sea having slight connection with the parent body. In the shore section there is no evidence for considering the beds above the limestones of other than continental origin. From the limestones Williams obtained fossils which Schuchert identified as *Beecheria davidsoni* (*Terebratula sacculus* Davidson), *Martinia glabra*, *Pugnax* sp., *Productus* cf. *doubleti*, and *P. dawsoni*. The thickness of the formation is 2045 feet (622 m.) (Williams).

Pennsylvanian.

Listmore formation.—The name Listmore has been proposed by Williams for a series of sandstones and shales, generally of red color which lie in apparent conformity on the Ardness formation. The deposits are of continental origin and contain imperfect specimens of *Stigmaria* and *Calamites* as the only organic remains. The thickness is 982 feet (299m.).

With this formation the sedimentary record closes and there were no other deposits laid down in the Arisaig region till the advent of the ice sheets when irregular masses of

sand and gravel were spread over some portions of the surface. Recent deposits consist of the stream gravels and soils.

Igneous Geology.— In the Arisaig region in the interval between the Lower Ordovician and Silurian and again during the Mississippian period there were intrusions of varied rock types. The Lower Ordovician rocks at some time subsequent to the deposition of the James River beds, but apparently before the laying down of the Malignant Cove conglomerate were intruded by quite large masses of granite and monzonite. Where fresh the granite is of a bright, flesh-red colour, very compact, tough and fine-grained and contains feldspar and quartz in the ratio of about 2 to 1. The areas of outcrop are south of Malignant cove and the intrusion appears to be in the form of a stock. The time of the intrusion was certainly subsequent to James River deposition and perhaps also Baxter's Brook, but prior to Malignant Cove time, since in thin sections of the last, Williams has found particles derived from the granites.

The monzonite outcrops on the shore about one half mile east of Malignant Cove. The intrusion appears to be in the form of a stock and consists of a medium granular rock in which white plagioclase feldspar and green hornblende are the chief constituents. The colour is a mottled green and white. Fragments of this rock are in the Malignant Cove conglomerate so that the time of the intrusion is probably to be placed in the same interval as the granite intrusives.

At the base of the Silurian section are splendid exposures of the upturned and eroded edges of a devitrified rhyolite flow. In places this passes into a flow breccia and at Frenchman's Barn, a large knob of rhyolite about a mile east of Arisaig village, there are considerable masses of breccia which may be the result of explosive action, but which Williams also considers flow breccias. Historically the rhyolite is of interest since it was considered by the earlier workers as having been produced by the metamorphism of sediments and *Eozoon* was reported from some portions of it. Cutting the rhyolite are large dykes of amygdaloidal diabase and a dyke of red shaly rock which cuts both rhyolite and diabase. In places the rhyolite shows flow structure and the color varies from grey

to green and black. The time of the extrusion was pre-Arisaig and since fragments of a similar rock occur in the Malignant Cove conglomerates it is probable that it was antecedent to the deposition of that formation.

Elsewhere in the Arisaig district are outcrops of rocks which Williams has called acid intrusives, consisting of dark colored rhyolite and quartz porphyry, the outcrops finding their greatest physiographic expression at Sugar Loaf hill (rhyolite) south of Malignant Cove and McNeil's mountain (quartz porphyry), just south of the Sugar Loaf hill and one of the highest points of the area. Associated at one or two localities are rhyolite flow breccias. The intrusions are in the form of dykes and larger masses which Williams has described as necks and cut either the James River and Baxters' Brook sediments or the James River granites. The available evidence points to their formation during the same phase of volcanic activity in which the rhyolite outflow at the base of the Silurian occurred. Also in the Malignant Cove—Sugar Loaf area are tuffs and breccias which are apparently interbedded and contemporaneous with the James River slates.

In the shore cliffs there are no rocks more conspicuous than the black dykes of amygdaloidal diabase or basalt. These cut all the strata except those of the Ardness and Listmore formations and are themselves cut by the red dyke. The intrusions are in the form of dykes and sheets and some may be flows. The largest observed intrusion begins at Arisaig pier and extends eastward for about three miles, but most of them do not have a width exceeding 100 feet (30 m.). The intrusions are all of one age as no diabase was seen to cut diabase. The fact that neither the Ardness nor the Listmore formations are cut by these dykes suggests that the time of the intrusions was pre-Ardness but it does not necessarily follow that this view is correct as there may not have been intrusions in the localities of the present outcrop of these rocks. The red dyke resembles a shale and on the basis of unpublished chemical analyses was considered such by the writer, but after more extended study, Williams is inclined to regard it as an intrusion. It cuts the diabase and may have been intruded during a later phase of that period of igneous activity.

THE ARISAIG FAUNAS AND THEIR CORRELATES.

Lower Ordovician.—*Obolus* (*Lingulobolus*) *spissa* from the upper James River slates also occurs in or associated with the oölitic iron ores of the Lower Ordovician of Belle Isle, Conception bay, Newfoundland. The occurrence of the same species with similar deposits at Arisaig leads to the correlation of the Arisaig measures with the Belle Isle rocks. The close stratigraphical relations of the Baxter's Brook beds with those of the James River hardly permits their separation and they are included therewith and considered part of the same system.

Ordovician?—The Malignant Cove formation contains no fossils so that its age determination depends on superposition. Since it is separated from the Lower Ordovician rocks by both an erosional and structural unconformity and appears to lie below the Silurian, it has been referred to the Ordovician (Williams).

Silurian.—The rocks of the Arisaig series are abundantly fossiliferous, but careful and painstaking collecting is required. Free fossils are not common. The number of species was given by Ami in 1891 as 162, of which about 100 have been described; but it is safe to say that the collections now in the various museums, particularly those of the Canadian Geological Survey, the U. S. National Museum, and Yale, will largely increase the above number.

The Silurian faunas taken as a whole predominate in pelecypods, as fully one-third of the species and specimens belong to this class of invertebrates. Brachiopods, generally the most abundant of Silurian fossils, at Arisaig hold second place, which place is attained by reason of the occasional deposition of lenses of relatively pure limestone and not because they are abundant in the sediments as a whole. Cephalopods and gastropods are about equally represented, though neither group has more than half a dozen species. Bryozoa and corals, usually so abundant in strata of this age, are almost wholly absent, the former being present in but a few stems of a ramose *Monticuliporoid*, while of the latter only a few specimens of a single species have been collected. Trilobites are relatively abundant. These faunal peculiarities with but little doubt are caused by the muddy character

of the habitat, which was extremely unfavourable to the corals, crinoids, bryozoa and many brachiopods, but apparently favourable to the pelecypods and not harmful to the trilobites.

The Silurian fossils of Arisaig in aspect are more European than American, but yet are unlike those of either country. Other than such cosmopolitan species as *Dalmanella elegantula*, *Leptaena rhomboidalis*, *Camarotoechia neglecta*, *Anoplotheca hemispherica*, and *Atrypa reticularis*, there is little else in the faunas that occurs elsewhere.

By reason of its nearness, the Anticosti faunas apparently should show close relations with those of Arisaig and although separated by less than 250 miles (400 km.), the two regions have less than ten species in common. The only portion of the Anticosti series with which a stratigraphic correlation can be definitely made is the lower Jupiter River formation in which are found *Monograptus clintonensis*, *Dalmanella elegantula*, *Plectambonites transversalis*, *Leptaena rhomboidalis*, *Anoplotheca hemispherica*, and *Calymene tuberculata*, all of which species are also present in the upper 633 feet (193 m.) of the Ross Brook formation. The Jupiter River sediments which contain these species are 80 feet (24 m.) thick and consist of highly calcareous shales which are succeeded by deposits containing a greater lime content and preceded by a 100 foot zone of slightly sandy shale underlain by sediments rich in lime. At Arisaig *Atrypa reticularis* appears for the first time in the second zone of the McAdam formation, but on Anticosti it makes its appearance below the *Monograptus clintonensis* horizon. Its later appearance at Arisaig may be due to the great amount of mud in the Ross Brook sea. The 80 feet of the Jupiter River rocks are the time equivalents of at least a part and perhaps the whole of the 633 feet of the Ross Brook formation, since it is very probable that the latter were accumulated far more rapidly than the former.

The succeeding Jupiter River rocks would correlate with the lower McAdam formation, but there is no similarity in either the lithology or the faunas. The Chicotte, the closing formation of the Anticosti series, carries a pronounced coral fauna and its rock consists largely of coral-reef limestone. Nothing similar exists in the McAdam formation, from which not a single coral has ever been collected. It is believed that the striking faunal

differences between Anticosti and Arisaig are to be referred to differences in the bionomic conditions existing at the time of deposition of the sediments.

Correlation with the Silurian of the interior is equally difficult. As before, the Ross brook faunas furnish the point of departure because the same fossils which have been mentioned above as occurring on Anticosti are also present in the Clinton of New York where also beds of hematite occur which, however, lie below the strata containing Monograptus instead of above as at Arisaig. The only New York formation which can be correlated with an Arisaig horizon is the Williamson shale with *Monograptus clintonensis* and *Anoplotheca hemispherica*. The presence of these two fossils in the Williamson shale leads to the conclusion that it is the time equivalent of the upper half of the Ross Brook formation. On this view the preceding Sodus green shale, the Furnaceville hematite bed, and the Wolcott limestone would find their time equivalency in the basal portion of the Ross Brook formation and the sandy limestones of the Beech Hill Cove formation. The common Clinton guide fossil, *Pentamerus oblongus*, which is so abundant in New York has not been found at Arisaig.

The Rochester, which succeeds the Clinton of New York, is thought to find its equivalency in the McAdam formation with which it has in common the species *Monograptus riccartoensis*, *Dalmanella elegantula*, *Leptaena rhomboidalis*, *Camarotoechia neglecta*, *C.* cf. *obtusiplicata*, *Atrypa reticularis*, *Spirifer crispus*, *Pterinea emacerata*, *Bucanella trilobata* and *Calymene tuberculata* or *niagarensis*. The Moydart formation has generally been considered the time equivalent of the Niagaran and in its faunal development it agrees best with the Waldron and Louisville of the United States. However, these formations have few fossils in common.

The Stonehouse formation has been variously correlated. Ami and Fletcher considered it as representing the Lower Helderberg, but it is difficult to see any Helderbergian affinities in this fauna. On a basis of its stratigraphic position the formation agrees best with the Guelph, but the two faunas are wholly different. On the other hand the Stonehouse faunas appear to be similar to those of the north European Ludlow, the equivalent of which in Gotland has, according to Lindstrom, Moberg, and others, the common Guelph fossil, *Megalomus*.

Correlation with the European faunas are not readily made, and until the Arisaig faunas have been completely studied there would appear to be little value in making the attempt in any great detail.

The presence in the Ross Brook fauna of *Dalmenella elegantula*, *Leptaena rhomboidalis*, *Plectambonites transversalis*, and *Anoplotheca hemispherica* indicates for this and the Beach Hill Cove formation a probable time equivalency with the Lower Llandovery of north Europe.

The highest beds of the McAdam formation contain *Monograptus riccartoensis* and *Spirifer crispus*, both of which are characteristic of the north European Middle Wenlock, and their common presence would lead to the reference of the highest beds of the formation to Middle Wenlock time while the great body of the formation should probably be placed in the Upper Llandovery. Other fossils common to the Upper Llandovery and the McAdam formation are *Dalmanella elegantula*, *Leptaena rhomboidalis*, *Atrypa reticularis* and *Calymene tuberculata*, all of which, however, also occur in the Wenlock.

The Moydart formation is marked by the earliest appearance of *Chonetes novascoticus*, which suggests, but is smaller than the European *C. striatella; Wilsonia wilsoni* (Ludlow of Norway, Wenlock and Ludlow of England); and *Spirifer subsulcatus*, a form of the *S. crispus* type but larger. *Calymene tuberculata* and *Leptaena rhomboidalis* are also present. The fauna is one suggesting an approach to the Ludlow, but still within the Wenlock.

The abundance of large *Chonetes* of the *C. striatella* type, *Rhynchonella nucula*, and *Schuchertella pecten* indicate for the Stonehouse formation an horizon equivalent to the north European Ludlow.

Devonian.—The Knoydart formation contains the remains of ostracoderm fishes whose closest generic relationships, as stated by Woodward, are with those occurring in the Old Red Sandstone of Europe. This indicates a lower Devonian age for the Knoydart strata. Their age can be determined, although less definitely, by another line of reasoning. The period of faulting in which the great fault of the Hollow was formed, is post-Knoydart and pre-Mississippian, since the rocks of the former are involved and those of the latter cross the fault. To the northwest before the close of Devonian time occurred disturbances which are expressed in the folds and faults

of the Gaspe region, and it is very possible that these are related in time and cause to the pre-Mississippian disturbance of the Arisaig region. Hence the time of deposition of the Knoydart clastics was previous to later Devonian time.

Mississippian.—The fossils from the limestone at the base of the Ardness formation are also present in the Windsor dolomites at Windsor, Nova Scotia, and in rocks of the same age on the Magdalen islands, thus leading to the reference of the Ardness formation to the Windsor series which, according to Schuchert* and Beede†, is the equivalent of the Kinderhook of the Mississippi valley.

Pennsylvanian ?—The Listmore rocks are difficult to place. Fletcher correlated them with the Millstone Grit which underlies the Coal Measures and is of Pennsylvanian age. The plant remains are uncertain and obscure and any correlation based on them would have but little value.

BIBLIOGRAPHY.

Reference is here made to only a few of the more important papers dealing with the Arisaig region. For a complete bibliography relating to the Silurian the paper by Twenhofel should be consulted as well as a forthcoming report of the Canadian Geological Survey by Williams.

1860. J. W. Daswon, on the Silurian and Devonian rocks of Nova Scotia, Can. Nat. Geol., vol. V, pp. 132–143.

1860. James Hall, Silurian Fossils of Nova Scotia, Ibidem, pp. 144–159.

1864. D. Honeyman, on the Geology of Arisaig, Nova Scotia, Quar. Jour. Geol. Soc. London, vol. XX, pp. 333–345.

1874. E. Billings, Paleozoic Fossils, vol. II, pt. I. pp. 129–144.

1887. Hugh Fletcher, Report on geological surveys and explorations in the counties of Guysborough, Antigonish and Pictou, Nova Scotia, Ann. Rept. Geol. Surv. Canada, vol. II, pp. 5P–128P.

1891. J. W. Dawson, Acadian Geology, 4th edition, London.

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*Schuchert, Geo. Soc. Am. Bull. 21, p. 551, 1910.
†Beede, New York State Museum. Bull. 149, p. 158.

1892. H. M. Ami, Catalogue of the Silurian Fossils from Arisaig, Nova Scotia, Nova Scotian Inst. Nat. Sci., n. ser., vol. II, pp. 185–192.

1909. W. H. Twenhofel, The Silurian Section at Arisaig, Nova Scotia, with a note on Correlation by Charles Schuchert, Am. Jour. Sci. 4th ser., vol. XXVIII, pp. 143–169.

1912. M. Y. Williams, Geology of Arisaig-Antigonish District, Nova Scotia, Am. Jour. Sci., 4th. ser., vol. XXXIV, pp. 244–250.

ANNOTATED GUIDE.

Antigonish to Maccan junction.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

Antigonish—Alt. 20 ft. (6 m.). From Antigonish westward, the Intercolonial railway for some miles follows the northern edge of a low-lying area occupied by strata of the Carboniferous Limestone series (Windsor series?), close to the bordering upland of older strata that stretches northward to the coast. For a short distance the railway lies on the north side of Rights river along which white cliffs of gypsum are visible, the strata dipping to the south at an angle of 40°. A short distance to the northeast rise high hills of deformed strata presumably of Ordovician age and intruded by basic igneous masses. At a distance of 1½ miles (2·4 km.) from Antigonish, the railway crosses Rights river and for a very short interval, enters an area occupied by the Carboniferous Conglomerate series; tilted, red sandstones and conglomerates of this series are exposed along the river. The strata of the Conglomerate series occupy an area several miles wide that extends northwards along a depressed area across the upland. To the eastward the strata of the Limestone series abut directly against the bounding Ordovician, but to the westward a narrow band of the Conglomerate series is interposed.

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About $\frac{1}{4}$ mile (0·4 km.) beyond the first crossing of Rights river, the railway again crosses the river and shortly re-enters the area of the Limestone series. The railway follows the river closely and along it occur cliffs of gypsum. The southern boundary of the Conglomerate series lies just north of the railway. The strata of this series dip in a general southerly direction at angles varying from quite low to as high as 70°. One mile (1·6 km.) beyond the second crossing of Rights river, the railway crosses it again where it issues from the higher ground to the north.

Beyond the third crossing of Rights river the railway passes along the sides of a series of small streams, the alternate ones flowing respectively east and west. Along the streams occur low cliffs of gypsum, while in places between the heads of streams the presence of gypsum is indicated by the characteristic "sinks". The Limestone series, as developed along the line of the railway, consists of a basal limestone member possibly about 10 feet (3 m.) thick overlain by about 200 feet (60 m.) of red sandstone and shale, above which lie about 200 feet (60 m.) of gypsum. The basal limestone rests on greenish conglomerate of the Conglomerate series which west of a point about $1\frac{1}{2}$ miles (2·4 km.) west of the third crossing of Rights river, is confined to a narrow zone bordering the steep front of the upland which rises a short distance north of the railway.

The steeply rising hills are underlain by closely folded greywacke varying to an impure quartzite and interbedded with a very siliceous slate. These measures compose the James River formation which is possibly 5,000 feet (1,500 m.) thick and is presumed to be of Ordovician age. The strata are penetrated by irregular intrusions of diabase and rhyolite and by one mass of granite underlying an area of several square miles.

About 8 miles (12·9 km.) from Antigonish the railway crosses James river, a southward flowing stream which issues from the hills through a deep, V-shaped valley. At the crossing of

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James river an extensive view is afforded to the south across the low-lying area of the Limestone series to the southern uplands of "Devonian" and older strata.

9·4 m. 15·1 km. **James River Station**—Alt. 203 feet (61·9 m.). The front of the uplands bordering the low area of the Limestone series on the north, strikes about southwest and a short distance beyond James river the railway enters the abruptly rising upland area by way of the deepset valley of Hartshorne brook. This valley and its continuation to the west, is underlain by Silurian strata forming a narrow strip rarely wider than ¼ mile (0·4 km.) bounded on both sides by a high, plateau-like upland occupied by Ordovician strata belonging in part to the James River formation and in part to the younger Baxter Brook formation which consists of reddish and greenish slates, and sandstones and conglomerates. The Silurian measures in places are fossiliferous and include shales, sandstones and limestones.

About 2½ miles (4 km.) from the entrance to Hartshorne brook valley, the head of the valley is reached and the railway crosses a low summit (altitude, 451 feet or 137·5 m.) separating Hartshorne valley from another valley drained by a small stream flowing westward to Barney river. Hartshorne brook as far as its head, occupies a pronounced, though narrow, deep-set valley. At the summit and on the divide, the valley contracts; to the west of the summit, the valley quickly widens, though still narrow, and is occupied by a small westerly-flowing brook whose volume is altogether disproportionate to the depth of the valley.

13·3 m. 21·4 km. **Marshy Hope Station**—Alt. 373 ft. (121·9 m.). At Marshy Hope station, the east branch of Barney river, flowing from the north, enters the valley traversed by the railway, at a point about 1 mile (1·6 km.) west of the summit. The tributary valley of the east branch of Barney river is very narrow and steep walled whereas the main valley through also narrow,

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is comparatively broad and its slope less steeply inclined.

Below Marshy Hope station the valley, for a distance of $1\frac{1}{2}$ miles (2·4 km.) continues to be underlain by Silurian strata everywhere confined to a narrow strip seldom more than 400 yards (365 m.) wide. Beyond this point the valley floor as well as the uplands, are occupied by the Ordovician strata. About 2 miles (3·2 km.) farther, the valley followed by the railway joins the broad valley of the main branch of Barney river.

17·2 m. 27·3 km. **Barney River Station**—Alt. 183 ft. (55·8 m.). Barney River station is situated on the west side of the comparatively wide valley of Barney river. This valley is underlain by folded and faulted Silurian measures occupying a low area about 2 miles (3·2 km.) broad bounded by steep slopes of Ordovician and igneous rocks. The Silurian area extends several miles to the south and then bends to the west. It extends about the same distance to the north to where the Silurian strata are overlapped by Carboniferous measures. The low-lying Silurian area is traversed by several streams which unite to form the northward flowing Barney river.

18·1 m. 29·1 km. **Dewar Station**—Alt. 160 ft. (48·8 m.). Dewar station is situated at about the centre of the Silurian area at the confluence of the two main branches of Barney river.

19·2 m. 30·9 km. **Avondale Station**—Alt. 151 ft. (46 m.). Avondale station is on the western side of the Silurian area close to the boundary with the Ordovician. About $\frac{1}{2}$ mile (0·8 km.) beyond Avondale station, the railway enters an area of Carboniferous strata extending to the sea coast, and turning through an angle of 90°, proceeds westerly near the northern foot of the upland area crossed by the railway and which separates the low-lying Carboniferous area on the north that extends westward to the Pictou coal field and beyond, from the equally low-lying area of the Antigonish Carboniferous

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area. The steep northern face of the upland extends along a fairly uniform northeast-southwest course. To the northeast the upland finally approaches the sea coast. In this direction, in the Arisaig district, the northern face of the upland marks a profound fault, presumably this is true also to the southwest. The upland in its extension both to the northeast and southwest is mainly underlain by Ordovician strata with large areas of igneous rocks. In places also, Silurian measures are largely developed.

Where the railway, a short distance beyond Avondale station, enters the Carboniferous area, the strata belong to the Limestone series and consist chiefly of grey and red sandstones with, towards the base, several beds of limestone. These measures, with low northeasterly dips, form a zone several miles wide extending in a northeasterly direction and in the immediate district rest directly on the Silurian strata. On the sea coast these rocks have a thickness of about 2,000 feet (600 m.) and on fossiliferous evidence have been correlated with the Windsor series.

At a distance of about 1½ miles (2·4 km.) from Avondale station, as the railway follows along the southern boundary of the Carboniferous at the foot of the upland of Ordovician, it leaves the area of the Limestone series and enters a district occupied by Millstone Grit which at the south boundary rests directly on the Pre-Carboniferous strata. The railway in this part of its course, ascends a valley, crosses a divide (altitude, 288 feet or 87·8 m.) and enters the valley of Huggan brook. From the neighborhood of the summit, a view to the northeast shows the sharply marked, nearly straight front of the upland of older strata and the low, rolling Carboniferous area extending from its foot to the sea.

23 m. 37 km. **Piedmont Station**—Alt. 241 ft. (73·5 m.). The Millstone Grit strata in the neighborhood of Piedmont station consist of grey and reddish shaly sandstones with coal-like matter; the

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basal member is composed of conglomerates reposing directly on the Ordovician strata forming the face of the upland. The Carboniferous measures dip to the northward, towards the sea at angles of 10° to 30°.

After leaving Piedmont station, the railway for a distance of about 1 mile (1·6 km.) continues to parallel the north face of the upland but beyond this point, the railway bends and runs towards the coast through a low broken country underlain by the Millstone Grit. A view of the sea is afforded at Merigomish.

27·8 m. **Merigomish Station**—Alt. 18 ft. (5·5 m.).
44·7 km. A short distance west of Merigomish station the railway crosses French river. Numerous exposures of Millstone Grit beds occur along the river. The strata consist largely of red and grey or greenish sandstones and shales with a few very thin coal seams and occasional thin beds of argillaceous limestone. The strata dip in a general way towards the north or west, and are traversed by a series of faults trending east and west.

From Merigonish the railway runs in a southwestward direction parallel to but about a mile distant from the shore of Merigomish harbour.

31·2 m. **West Merigomish**—Alt. 77 ft. (23·5 m.).
50·2 km. The Millstone Grit strata extend westward past West Merigomish to the border of the area of Productive Coal Measures of the Pictou coal field.

Beyond West Merigomish station, the railway swings around the head of Merigomish harbour and from the railway a good view is obtainable of the low islands and irregular shores of this indentation of the sea. About 3 miles (4·8 km.) beyond West Merigomish the railway crosses the mouth of Pinetree brook. One-half mile (0·8 km.) farther, the railway enters an area occupied by the New Glasgow Conglomerate which forms a ridge extending westward to New Glasgow. These measures consist of red conglomerates with lenticular beds of sandstone;

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they dip to the north at angles of 15° to 30°, and occupy a band having a breadth of somewhat more than ½ mile (0·8 km.). Along their south boundary the strata have been described as unconformably overlying Millstone Grit; along their northern boundary they are conformably succeeded by sandy shales forming a very thick series displayed over a large area for many miles to the west. By Fletcher, the New Glasgow Conglomerate was considered to mark the base of the so-called Permo-Carboniferous or Permian series.

As the railway ascends the ridge underlain by the New Glasgow Conglomerate, a view opens up across the head of Merigomish harbour and the low, rolling Millstone Grit country beyond, to the high abruptly rising upland of pre-Carboniferous strata already traversed by the railway. The railway crosses nearly the whole width of the band of New Glasgow Conglomerate but before reaching the northern boundary, turns to the westward and for some distance runs parallel with it.

35·6 m. 57·3 km. **Woodburn Station**—Alt. 136 ft. (41·4 m.). From Woodburn station, for a distance of about 1 mile (1·6 km.) the railway continues within the area of the New Glasgow Conglomerate. Beyond this it enters the "Permo-Carboniferous" area.

Some distance farther, the railway crosses a low divide (altitude 218 feet or 66·4 m.) and enters the valley of Smelt brook. From the summit, the country to the north may be seen to be low and gently rolling. As the railway descends the valley of Smelt brook, occasional outcrops of grey "Permo-Carboniferous" sandstone are visible. Before reaching the mouth of Smelt brook, the railway turns to the south, follows up the east side of East river, and recrosses the belt of New Glasgow Conglomerate exposed along the banks of the river within the limits of the town of New Glasgow. The railway station is situated a very short distance south of the

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conglomerate band, within the area of the Productive Coal Measures of the Pictou field.

41·5 m. 66·8 km. **New Glasgow**—Alt. 29 ft. (8·8 m.). The railway route between New Glasgow and Truro is described on pages 222 to 229.

84·4 m. 135·8 km. **Truro**—Alt. 60 ft. (18·3 m.). From Truro the Intercolonial railway runs westerly through the Triassic area extending along the north side of the Bay of Minas. The country underlain by the Triassic is low and rises very gradually from the shore of the Bay of Minas. The northern boundary of this area lies at a variable distance, in most places between 1 and 2 miles (1·6 km. and 3·2 m.), north of the railway and is marked by the abruptly rising front of an upland which merges farther inland, into the Cobequid hills.

The hilly district bordering the Triassic area on the north is in part underlain by measures of the Riversdale-Union group lying with steep angles of dip in a series of east-west folds. The Triassic strata are mainly red conglomerates and sandstones, which are in general, horizontal or dip at low angles except along the northern border where the strata are usually inclined at angles of 30° to 45°.

91·9 m. 147·9 km. **Belmont Station**——Alt. 84 ft. (25·6 m.).

97·8 m. 157·4 km. **East Minas Station**—Alt. 193 ft. (58·8 m.). In this district the Triassic area extends inland for from 5 to 6 miles (8 to 9·6 km.). To the westward, the band of Triassic strata continues for many miles along the coast of the Bay of Minas and in places the sediments are associated with diabase or basalt. The igneous rock in general occurs in large sheet-like bodies overlying the sediments; in some cases, at least, the masses are dyke-like or are sills.

At East Minas station, the northern boundary of the Triassic sediments lies about 1 mile (1·6 km.) north of the railway and there the Triassic is in contact with strata mapped as Carboniferous Conglomerate (lowest Carboniferous) by Fletcher. This area of the "Car-

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boniferous Conglomerate" extends for many miles both to the east and west, in the form of a band varying in width between 1 and 2 miles (1·6 km. and 3·2 km.). Along the northern edge of this band of "Carboniferous Conglomerate" occur so-called Devonian strata of the Riversdale-Union group, and from a point not far east of East Minas station, the same "Devonian" beds lie along the southern boundary of the Conglomerate series between it and the Triassic. The "Carboniferous Conglomerate" measures strike in a general east and west direction and dip either to the north or south at angles of 20° to 75°.

One mile (1·6 km.) west of East Minas station, the railway crosses Folly river. This river flows across the band of "Carboniferous Conglomerate" whose southern boundary lies ½ mile (0·8 km.) north of the railway. The strata of the conglomerate series comprise not only conglomerates but also reddish and greyish sandstones and shales with very thin seams of coal. By Fletcher the conglomerates are described as holding fragments of the "Devonian" rocks. By Sir William Dawson, the strata were classed with the "coal measures" and not with the basal Carboniferous as Fletcher did.

Beyond the crossing of Folly river, the railroad gradually approaches the southern boundary of the "conglomerate series" and finally, after curving around to a nearly north course, enters the area of these rocks. The railway passes through several cuttings in inclined red conglomerates and sandstones belonging to this series.

101·3 m. **Londonderry Station**—Alt. 334 ft. (101·8m.).
163·0 km. From Londonderry station, situated within the area of the "Conglomerate" series, the railway as it climbs the southern slope of the Cobequid hills, runs in a northeasterly direction towards the valley of Folly river. Cuttings in red conglomerate and sandstone, and in red sandstone and shale, occur along the railway. As the railway approaches Folly river, a view is afforded to the south and east over the low

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Triassic area along the shore of the Bay of Minas and 15 to 20 miles (24 to 32 km.) to the eastward, are visible the hills of "Devonian" strata rising on the southern side of the Salmon river valley, beyond Truro.

Where the railway enters the valley of Folly river it turns to the north, and keeping to the west of the stream, follows the valley northward across the Cobequid hills. About where the railway finally enters Folly river valley, it crosses the northern boundary of the "Conglomerate series." All along this boundary, for a number of miles to the east and west, the lowest member of the "Conglomerate series" consists of conglomerates holding pebbles and boulders up to 1 foot (30 cm.) in diameter of the bordering "Devonian" strata and of the igneous rocks that penetrate the "Devonian" and underlie by far the greater part of the area of the Cobequid hills. The "Devonian" strata in places have yielded plants precisely similar to those of the Riversdale-Union group and it is quite certain that the "Devonian" of the south flank of the Cobequid is in part at least, the equivalent of the Riversdale-Union group.

The "Devonian" beds both to the east and west of Folly river are traversed in an east and west direction, by a zone of fissuring occupied by veins of ankerite, siderite, etc., and masses of limonite and hematite. These deposits for many years were mined and the ore smelted at Londonderry.

The "Devonian" strata in general have been metamorphosed to a considerable degree. Quartz veins are common. In places the rocks are schistose, and they are penetrated by various types of igneous rocks. In these respects, they differ from the strata customarily classed as Carboniferous and therefore, notwithstanding the palæobotanical evidence, Fletcher classed them as Devonian. If the so-called "Devonian" is not Devonian but is approximately of Millstone Grit age, then the strata of the band of "Conglomerate series" to the south may be

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of the age of the Coal Measures as stated by Dawson, or even younger.

The zone of "Devonian" strata lying north of the belt of the "Conglomerate series" is quite narrow where crossed by the valley of Folly river. Beyond the Devonian, occurs a complex of igneous rocks that with a length in an east and west direction of about 100 miles (160 km.) forms the central part of the Cobequid hills. Where traversed by the railway, the igneous complex has not been studied petrographically but is known to contain many types including granite, diabase, and fine-grained acid and basic intrusive rocks. Areas of schistose rocks, in part of sedimentary origin, are associated with the igneous rocks.

The railway enters Folly valley at a considerable elevation above the river but in a comparatively short distance, as a result of the steep gradient of the valley bottom, the railway track and the stream possess the same altitude. The river rises in Folly lake (altitude 605 feet or 184·4 m.) along whose eastern shore the railway runs. The upper part of the valley, to the head of Folly lake, is comparatively broad and the hills on either side rise gradually to heights of 100 to 200 feet (30 to 60 m.) above the valley.

Numerous cuttings in igneous rocks occur along the railway.

108·8 m. **Folleigh Station**—Alt. 618 ft. (188·4 m.).
175·1 km. Folleigh station is situated near the head of Folly lake. Beyond the end of the lake, the valley contracts and the railway crosses a low divide (altitude 618 feet or 188·4 m.) and enters the valley of a northward flowing brook, the headwaters of Wallace river. As the divide is left behind, the valley broadens and rapidly deepens so that the railway tracks run high on the valley side. Before reaching Wentworth station the valley opens widely and the hills on either side sink abruptly to lower levels. To the north an extensive view is displayed over a low rolling country stretching northward to Northumberland strait. A band of strata of

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the Carboniferous Limestone series and of the Millstone Grit, several miles broad, runs along the northern flanks of the Cobequid hills while the lower country to the north is underlain by gently dipping Permo-Carboniferous strata.

113·5 m. 182·6 km. **Wentworth Station**—Alt. 472 ft. (134·8 m.). Wentworth station lies almost on the northern edge of the igneous area of the Cobequid hills. Bordering the igneous complex at this point for a length of about $2\frac{1}{2}$ miles (4 km.) in an east and west direction, is an area of Silurian rocks having a maximum width of about $\frac{3}{4}$ miles (1·2 km.). The strata consist mainly of highly inclined dark slates which in places are fossiliferous and apparently are of Clinton age.

Beyond Wentworth station, the railway enters this limited Silurian area and as it curves around to the west on the steep northern slope of the Cobequids, a splendid view is obtainable across the low country to the north. At a distance of about $1\frac{1}{2}$ miles (2·4 km.) from Wentworth station, the railway enters a belt of strata consisting largely of shales and sandstones considered by Fletcher to belong to the Carboniferous Limestone series. These measures directly overlie the igneous rocks of the Cobequid hills and with a width of 1 to 2 miles (1·6 to 3·2 km.) stretch for a number of miles both to the east and west. The strata dip northwards at angles of 10° to 40°.

118·0 m. 189·9 km. **Westchester Station**—Alt. 299 ft. (91·1 m). Westchester station is situated on the northern margin of the narrow band of the limestone series. To the north, for a width of about 2 miles (3·2 km.), the low, broken country is underlain by strata assigned to the Millstone Grit and consisting mainly of an assemblage of conglomeratic strata overlain by sandstones and shales. The strata dip to the north at angles of 30° to 12°.

119·3 m. 192 km. **Grenville Station**—Alt. 290 ft. (88·4 m.). Grenville station is situated near the northern boundary of the Millstone Grit conglomerate. The Millstone Grit sandstones and shales occupy

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a zone about $\frac{1}{2}$ mile (0·8 km.) in width beyond which they are overlapped by Permo-Carboniferous measures dipping northward at low angles.

Beyond Grenville station, the railway follows a general northwesterly course and passes diagonally across the remaining width of the Millstone Grit. From the railway the steeply rising north front of the Cobequids is visible at intervals. Two and a half miles from Grenville station the railway enters an area underlain by Permo-Carboniferous strata. These beds terminate a short distance west of the railway but extend eastwards to New Glasgow 50 miles (80 km.) distant. The strata with very low angles of dip lie in an open synclinal fold pitching to the east. The railway in a distance of about 4 miles (6·4 km.) crosses the western end of this syncline of Permo-Carboniferous and enters an area of Millstone Grit strata dipping to the southward at low angles and extending to the northeast as a border to the Permo-Carboniferous area. To the north, an anticlinal fold brings measures of the Limestone series to the surface, while on the northern limb of this anticline the Millstone Grit followed by Permo-Carboniferous strata are again repeated.

From where the railway leaves the synclinal area of Permo-Carboniferous, to Springhill Junction, 17 miles (27·3 km.) west, the railway crosses an area in which the strata have been folded along axes pursuing a general northeasterly direction. Subsequent to the folding, the measures have been crossed by heavy faults some of which strike in a north-south direction while others follow courses that are approximately east-west, northeast-southwest, or northwest-southeast. The strata range from the Limestone series to Permo-Carboniferous and the whole assemblage behaves as a conformable series. The Limestone series is characterized by the presence of beds of gypsum and of fossiliferous limestone. The Productive Coal measures are present, and

Miles and Kilometres.

in the coal field centering about Springhill, contain 8 coal seams ranging in thickness from 2 feet to 13 feet (0·3 m. to 3·9 m.).

143·5 m. 230·9 km. **Springhill Junction**—Alt. 199 ft. (60·6 m.). A short distance to the east of Springhill Junction, the railway enters an area of Permo-Carboniferous measures lying in a broad synclinal basin that stretches westward for about 20 miles (32 km.) to the Bay of Fundy where the measures form the upper portion of the famous Joggins sections. In the neighborhood of Springhill Junction, the Permo-Carboniferous strata appear to conformably overlie Millstone Grit strata, whereas along the northern margin of the basin, they appear to conformably overlie the Productive Coal Measures.

For a distance of about 8 miles (12·8 km.) from Springhill Junction, the railway traverses the Permo-Carboniferous area. Beyond this it crosses the northern boundary of the Permo-Carboniferous and enters the band-like area of Productive Coal Measures which with a width of about 1½ miles extends easterly to the Joggins coast. Maccan Junction lies about in the centre of this band-like area.

152·6 m. 245·6 km. **Maccan Junction**—Alt. 31 ft. (9·4 m.).

ANNOTATED GUIDE.

MACCAN JUNCTION TO JOGGINS.

(G. A. Young.)

0 m. 0 km. **Maccan Junction**—Alt. 31 ft. (9·4 m.). From Maccan Junction to Joggins, the Maritime Coal, Railway and Power Company railway passes over an area underlain by the Productive Coal Measures. These beds form a band about 2 miles (3·2 km.) wide in which the strata dip southwards, at angles of 15° to 40°, beneath overlying Permo-Carboniferous measures.

Miles and Kilometres.

Leaving Maccan Junction, the railway crosses Maccan river and ascends to the top of a broad ridge (altitude 220 feet, or 67 m.). The dumps of various small collieries may be seen along the railroad line. From the summit of the ridge, the Cobequid hills are visible about 15 miles (24 km.) to the south on the opposite side of the open syncline of Permo-Carboniferous and Carboniferous strata.

After crossing the broad ridge, the railway descends to the wide valley of River Hebert.

7·1 m. **River Hebert Station**—Alt. 29 ft. (8·8 m.).
11·4 km. River Hebert station is situated near the southern boundary of the band of Productive Coal Measures and in this neighborhood are several active collieries. From this station the railway ascends the long western slope of River Hebert valley and passes through a gently rolling country (summit level, 191 feet or 60·9 m.) to Joggins.

11·6 m. **Joggins Station**—Alt. 58 ft. (17·7 m.).
18·6 km.

THE JOGGINS CARBONIFEROUS SECTION.*

(W. A. Bell.)

INTRODUCTION.

The Joggins section, Nova Scotia, is a great pile of Carboniferous rocks which faces to the north on Chignecto bay, the northern arm of the divided head of the Bay of Fundy. By the work of the powerful Fundy tides, which here rise to heights of 40 to 50 feet (12 to 15 m.), this section is happily opened to view in a flat, monotonous, waste-mantled region of few rock outcrops. Though lacking in great mineral wealth the majesty of the great thickness of Carboniferous rock exposed, as well as the ancient forests entombed therein, has won for it the homage of geologists. As to its regional importance the Joggins

*See Map—Logan's section of the Carboniferous at Joggins Mines.

section exposes an oblique cutting through an entire coal basin, known as the Cumberland Coal basin.

This basin is in the form of a broad synclinal trough, having a width of about 25 miles (32 km.), trending in a general east-northeast direction in conformity with the regional Appalachian structure, and paralleling a youthful dissected old land to the south, the Cobequid hills. To the north the basin is limited by a well defined anticline and a narrow belt of subsidiary folds, referred to as the Minudie anticlinorium, but rocks considered to be equivalent to basal members of the Joggins series extend with nearly horizontal attitudes beneath the southern lowlands of New Brunswick.

From the Chignecto shore eastward, the syncline preserves its general regularity of structure for 20 miles (32 km.) inland, where transverse folds and faults again bring up the lower rocks of the series in a belt some 12 miles (19 km.) wide, which is partially occupied by the watershed between the Bay of Fundy and Northumberland strait. From here eastward to the Strait the synclinal character of the trough is again manifest, but more noticeably interrupted by secondary parallel folds, until it sinks gently beneath the waters of St. Lawrence gulf. In the extreme southeast, however, it is no longer limited so completely by the Cobequid plateau, but, passing around several outliers of older rocks, merges into the Pictou Coal basin.

PHYSICAL FEATURES.

The whole area underlain by the Carboniferous rocks forms the Cumberland lowland, as contrasted with the pre-Carboniferous Cobequid upland to the south. The surface of the lowland is everywhere nearly plain or gently rolling, with an average elevation of little over 200 feet (61 m.) above the sea, but rising gently to the base of the Cobequids to elevations of over 300 feet (91 m.), and then rapidly to the 800 (244 m.) to 1,000 feet (305 m.) elevations of the upland surface. The monotonous character of the lower plain is broken, however, by low rolling ridges developed on the harder sub-rock, and by a few isolated monadnocks, such as Springhill (610 feet, 186 m.), Claremont hill (565 feet, 172 m.), and the Salem hills (450 feet and 390 feet, 137 m. and 180 m.). Such a residual is also present in

New Brunswick, across the bay from the Joggins, in the form of Shepody mountain, which rises to an elevation of 1,050 feet (320 m.).

Yet, properly, this Cumberland lowland is but a portion of a much more extensive Carboniferous lowland of eastern Nova Scotia and New Brunswick, whose surface is broadly characterized by its truncation and disregard of underlying structure, thus constituting a part of a true peneplaned surface which has been referred by Daly to the Tertiary epoch.

The Cobequid upland is a higher residual plateau surface representing a remnant of a once extensive and continuous uplifted older peneplain, whose several surviving portions now form the Cobequid upland, the Southern plateau of Nova Scotia, and the Caledonian and neighboring highlands of New Brunswick. Daly has correlated this higher peneplain surface with the Cretaceous peneplain of New England, and it has suffered in like manner a southeasterly tilting movement, so that the elevations progressively increase to the northwest. The Cumberland lowland is then, on this theory, but a portion of a local peneplain carved in Tertiary time in the softer Carboniferous rocks of an elevated and warped Cretaceous peneplain. The Cobequids might then be considered as a residual mass of the Unakian type.

Late Tertiary history has been expressed by oscillatory vertical movements of lesser amount, resulting in the dissection, below the general surface of the lowland, of narrow valleys whose mouths have subsequently been drowned and converted into tidal estuaries. Tidal deposition, resulting in the aggradation of wide fertile flats of marsh along the upper reaches of the Bay of Fundy, has been, aside from glacial action, the most recent and conspicuous process, and one whose activity and effects may still be observed in this region.

GENERAL GEOLOGY.

The pre-Carboniferous rocks of the Cumberland area are confined to the region of the Cobequid upland, and consist of folded and metamorphosed early Palæozoic and Pre-Cambrian (?) sediments, intruded by Pre-Cambrian (?) and Palæozoic plutonic and volcanic masses, the whole being known as the Cobequid series. Sufficiently detailed work

has not yet been done to state adequately the relations of the rocks of this complex series, but the Cobequid upland is underlain predominantly by plutonic and volcanic masses ranging in acidity from diabase to acid granites. The originally intruded sedimentary roof is present now in the central areas only as scattered remnants, but in the southern belt of the upland there is a considerable development of altered sediments, which are chiefly dark quartzites, black slates, red and green argillites, green micaceous and chloritic schists, and small areas of crystalline limestone. At Wentworth station a small outcrop of fossiliferous slates carries Silurian fossils, and Dawson on lithological grounds has assigned the remaining unfossiliferous quartzites and slates to the Silurian with the exception of a few plant-bearing beds doubtfully referred to the Devonian but which are seemingly of Pennsylvannia age.

Fletcher and Selwyn have regarded the entire Cobequid series as altered Silurian and Devonian sediments cut by post-Devonian intrusives. Ells, on the contrary, has considered these rocks as predominantly Pre-Cambrian in age, but with Cambro-Silurian sediments flanking the range on the north, and with an isolated outcrop of Silurian at Wentworth station.

The Carboniferous rocks are not exclusively confined to the Cumberland lowlands, as several outlying or inlying conglomeratic remnants occur as isolated patches on the Cobequid series.

HISTORICAL NOTES.

The Joggins section early attracted the attention of geologists by the reported occurrences of many fossilized trees still standing erect in the sandstone. In 1842 Sir Charles Lyell made his first visit to this locality and was impressed by the abundance of erect trees to be seen, as stated in one of his letters:

"Whither I went to see a forest of fossil coal-trees—the most wonderful phenomenon perhaps that I have seen, so upright do the trees stand, or so perpendicular to the strata . . . . trees twenty-five feet high, and some have been seen of forty feet, piercing the beds of sandstone and terminating downwards in the same beds, usually coal. This subterranean forest exceeds in extent and quality of timber, all that have been discovered in Europe put together."

Unfortunately the present stand of the fossil timber is not so striking, owing in some measure to the destructive tendencies of fossil hunters. In 1852-53 Lyell restudied the section in the company of Sir William Dawson. Since then his drawings of these logs and those of Dawson have appeared in many text books on geology.

Sir William Logan in 1843 published a careful description and detailed measurements of the northern limb of the Joggins syncline, as exposed from Mill creek at the base of the section to the uppermost beds of Shulie. In recognition of the seeming continuity in the sedimentation of his 14,570 feet (4,441 m.) of strata, he divided the section more or less arbitrarily into eight divisions, but each group was characterized on the whole by a dominance of certain characters. Fresh from his experience in the British coal fields, he was the first to appreciate the significance of the numerous ancient soil beds and underclays, so well exposed to view, as illustrating the formation of coal in situ.

Dawson in his second edition of the "Acadian Geology" in 1868 presented an accurate and very readable account of the regional geology, with many additional detailed observations on the sedimentary sequence and mode of origin of the beds, and with illustrations and descriptions of the characteristic flora and fauna.

To Fletcher and Ells of the Canadian Geological Survey are chiefly due former interpretations of the difficultly ascertained structure of the largely concealed inland portions of the basin.

DETAILED DESCRIPTION.

TABLE OF FORMATIONS.

The classification of the Carboniferous rocks as presented here is a provisional one, and the older terminology is included for comparison.

	Older classification.
JOGGINS SERIES.	
Late Pennsylvanian—	
Shulie formation—	
(Thickness 2,136 ft. (658 m.)—Logan.)	Permo-Carboniferous.
Uplift and renewed erosion.	
Middle Pennsylvanian—	
Joggins formation—	
(Thickness 6,886 ft. (2,099 m.)—Logan).	Productive Coal Measures.
Early Pennsylvanian—	
Boss Point formation—	
(Thickness 4,583 ft. (1,397 m.)—Logan).	Millstone Grit.
Disconformity.	
Mississippian—	
Windsor formation—	
(Thickness 2,000 ft. (610 m.), roughly estimated.)	Lower Carboniferous.
Unconformity.	
COBEQUID SERIES.	
Pre-Mississippian	
Pre-Cambrian and pre-Devonian altered sediments.	
Pre-Cambrian and Palæozoic igneous intrusives.	

The Joggins section is naturally divisible into five major divisions, none of which is sharply delineated, but each is the effect of peculiar conditions of sedimentation. These are briefly: (a) a lower marine limestone and red shale division of Mississippian age, called the Windsor formation; (b) a conglomerate, grey sandstone, and shale division of Pennsylvanian age, of fresh-water origin, and containing plant remains and thin coal seams, comprising the Boss Point (Millstone Grit) formation; (c) a barren red shale division included in the succeeding Joggins formation; (d)

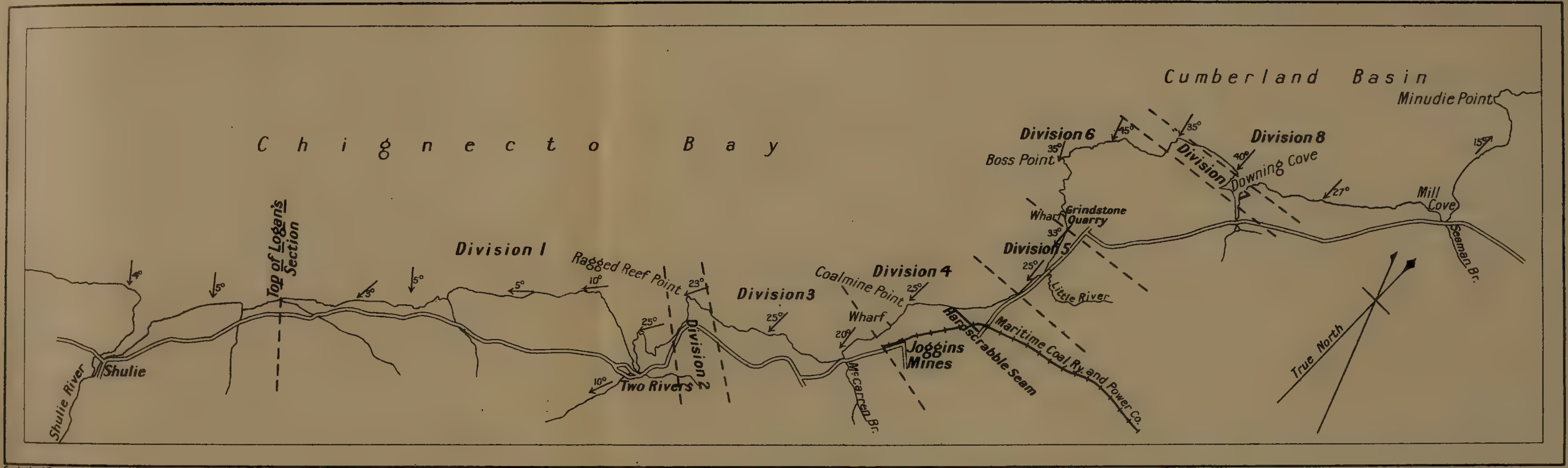
a sandstone and shale division of terrestrial origin, with plant remains and productive coal seams, forming the typical Joggins formation; and lastly (e) an upper conglomeratic division also of terrestrial origin, comprising the Shulie formation. A brief description of each formation is given below.

LOWER PART OF SECTION: TO LOWER COVE.

Windsor formation.— Below the Joggins section, in the axial region of the Minudie anticlinorium, near Minudie, there may be seen at low tide some 50 feet (15 m.) or more of black and nodular limestone, associated with red and green shales and calcareous sandstones. The calcareous beds carry a scanty fauna related to that of the upper limestone at Windsor, of Mississippian age. The extension of these beds at Nappan and across the bay in New Brunswick is associated with a thick zone of gypsum, but this mineral is concealed in the low area below the Joggins section. Lying conformably above these definitely marine beds, there are upwards of 2,000 feet (610 m.) of barren, brick red, arenaceous and argillaceous shales, of which the upper 966 feet (299·4 m.) are well exposed at the base of the Joggin section. These soft red beds underlie a belt of low country about $2\frac{1}{2}$ miles (4·2 km.) in width, striking in an easterly direction from Cumberland bay to the river Hebert. The shales contain abundant flakes of mica, and from their rippled, mud-cracked and cross-bedded character are believed to be the deposits of a receding Mississippian sea and are hence included in the Windsor formation. A greater development of the beds is exposed across the bay in New Brunswick where the upper deposits are distinctively calcareous, the lime occurring in the form of thin beds, seemingly of chemical deposition, or as numerous concretions in bright red shales and conglomerates. These rocks dip uniformly about 27° southward.

Post-Mississippian unconformity.— Post - Mississippian orogenic movements followed by uplift and erosion before the deposition of the Pennsylvanian rocks, are marked in many areas of Nova Scotia and New Brunswick by erosional unconformities. At the Joggins section, however, the unconformity is accordant, and is therefore distinguished by the term disconformity. It occurs at the

A1.



Geological Survey, Canada.

Logan's Section of the Carboniferous at Joggins Mines

Miles
Kilometres

base of the lowest bed of grey sandstone in the Boss Point formation. These overlying Boss Point beds are characterized by the presence of grey sandstone bearing abundant, though frequently generically obscure, drift plant debris indicative of Pennsylvanian time, and by the occurrence of basal quartz conglomerates seemingly derived from the erosion of upper beds of the underlying Windsor. The geological history represented by this depositional break must be largely of a speculative nature until further regional data are obtainable.

It is probable, however, that the Cobequid mountains were established as a region of uplift in early Palæozoic times, and partook of the orogenic movements of late Silurian and post-Silurian times, which took place generally in western New England, and still later possibly they may have suffered post-Devonian deformations. At least the faunal and structural evidence points to the existence of the Cobequids as highlands or islands in the Mississipian sea.The post-Mississippian orogenic movements were Appalachian in character with the thrust from the south, and highly disturbed the Windsor strata in the basin south of the Cobequids, but seemingly little affected these to the north of the Cobequids. Contemporaneous or later vertical movements then initiated a period of active erosion and the deposition of terrestrial deposits in the form of fluvial flood plains and subaerial delta deposits which were derived in part from the large continuous areas of upland to the south and west, and in part from the forelying Appalachian mountain chains. Of these mountain ridges, the Cobequids were sufficiently developed to delineate the two main Carboniferous basins of Nova Scotia. The southern or deeper basin which lay between the Cobequids and the Southern uplands was an area of estuarine or brackish-water deposition resulting in the Riversdale deposits. In the north the Cumberland and the southern New Brunswick basins were seemingly continuous and this area was one of contemporaneous terrestrial fluvial deposition, giving rise to the Boss Point (Millstone Grit) sediments.

Boss Point Formation—The Boss Point formation continues westward from the Windsor belt for about 5 miles (8 km.), and consists primarily of two distinct divisions, a lower prevailingly red division, and an upper predominantly grey division. The lower division contains considerable conglomerate which is characterized by the

presence of well rounded pebbles of varicolored vein quartz and quartzites, embedded in a matrix of sharp or subangular sand grains and red ferruginous cement, the pebbles ranging in size up to 3 inches in diameter. In addition, occasional grey limestone pebbles occur. Within this formation, as exposed in the Joggins section, siliceous conglomerates are confined to these basal members, but in New Brunswick, conglomerate is, however, as mentioned above, of common occurrence, not only in the lower division, but throughout the formation, in the form of lenticular beds which channel into the underlying grey sandstones or shales.

The succeeding division is the one especially characteristic of this formation, and consists mainly of greenish grey, yellow or buff weathering sandstones interbedded with brick red argillaceous shales, but with subordinate grey and black carbonaceous shales, as well as thin seams of coal and of fossiliferous bituminous limestone. The latter may carry *Leperditia*-like ostracods, *Anthracomya ovalis* (Dawson), *A. laevis* (Dawson), coprolites as well as scales and teeth of Crossopterygian and Chondrostean ganoids. The flora has not yet been worked out in detail, but the commonest forms are drifted trunks of *Dadoxylon acadianum* Dawson, *Calamodendron*, *Stigmaria ficoides* Brongniart, *Sigillaria*, *Calamites* and leaves of *Cordaites*, all of which are also found in the succeeding formation.

Middle part of section: Lower Cove to McCarren Brook.

The typical sharp quartz sandstone of the formation occurs at Boss point and at an abandoned quarry at Lower cove, where, in the past, the rock from the reefs was extensively worked into grindstones. The frequent occurrence, however, of hard concretions and of drifted plant material must be a serious defect of this stone.

Joggins Formation—The sandstones of the quarry at Lower Cove are succeeded by 2,000 feet (610 m.) of red beds which because of their lithological contrast with the underlying Boss Point measures, and for other reasons, indicate the possibility of a disconformity existing beneath this horizon and are therefore classed with the Joggins formation.

It is thought that the 2,000 feet of red shales may be the equivalent of certain red conglomerate and associated

strata occurring at Spicer's Cove at the western end of the Joggins section. It should be stated however that the conglomerates, etc., of Spicer's Cove were held by Fletcher to possibly represent the New Glasgow conglomerate and therefore to be of Permo-Carboniferous age. It is interesting to note here that a somewhat similar thickness of brick red conglomerates, soft sandstones and shales occurs in a belt immediately to the north of the Minudie anticlinorium in New Brunswick seemingly overlapping the Boss Point beds unconformably, suggesting that these too may represent in part synchronous deposits of the Joggins formation but with the material largely derived from the New Brunswick highlands to the north(?) and west. This is supported, moreover, by the fact that fragments of a very poorly preserved *Lepidodendron* like that of a species commonly occurring in the Joggins formation have been seen in these rocks. These rocks have been mapped by Ells as Permo-Carboniferous.

Aside from their importance in the above theoretical consideration, these almost barren red beds are without any special interest. Their softness in comparison with the rocks above and below has resulted in the formation here of a low depression. From any point along this shore, however, may be had an excellent view of the succeeding rocks of the Joggins formation, which are exposed continuously with great regularity of dip (20°+) for more than 4 miles (6·5 km.) or to the vicinity of Ragged Reef point. On a clear day this view may be extended across the bay into New Brunswick where the monadnock mass of Shepody mountain may be clearly seen, rising conspicuously above the gently sloping plains of Carboniferous rocks which there form a low foreland 4 miles (6 km.) in breadth, skirting the Caledonian upland. The Carboniferous rocks there exposed belong exclusively to the Windsor and Boss Point formations, and the Cumberland syncline apparently curves sharply to the south underneath the waters of Chignecto bay. Even from the Joggins shore, the rocks of the Boss Point formation may be seen to strike uniformly in a westerly direction across to the Maringouin cape, but along the farther shore of the New Brunswick mainland they strike southwesterly about parallel to the coast and dip steeply at angles greater than 45° beneath the bay.

Shepody mountain itself lies in line with the Minudie anticlinal, which may then be considered as deflected to the

southwest parallel to the present outline of the New Brunswich coast. The Carboniferous area lying to the westward of Shepody mountain is therefore an integral part of the Cumberland synclinorium, or it represents more properly the extension of the Minudie anticlinorium.

The remaining strata of the Joggins formation are the most interesting in the Joggins section both on account of their organic remains and their economic importance. The beds differ from the preceding beds of the Boss Point formation chiefly in those characters resulting from deposition under more pluvial or swampy conditions. Thus the measures are predominantly grey in color, the sandstones are generally much thinner, and are replaced or interbedded with thick or thin zones of red, grey, or variegated shales in which the coals or carbonaceous beds occur. It will be seen that the division of this formation into unequal zonal groups may be conveniently made in the field, since there is a noticeable monotonous sequence of zones of regularly evenly-bedded shales, thin sandstones, underclays, coals and thin bituminous limestones, in alternation with massive falsely-bedded sandstones that characteristically channel into the underlying shale zones. The rapid deposition of these heavier sandstone beds is well attested by the fact that they frequently contain the casts of erect trees which occasionally exceed 20 feet in length and whose bases occur in the mudstone soils beneath. That these soil beds are extremely abundant throughout the whole formation, may be seen from the widespread vertical recurrence of shale beds with rootlets (*Stigmaria*).

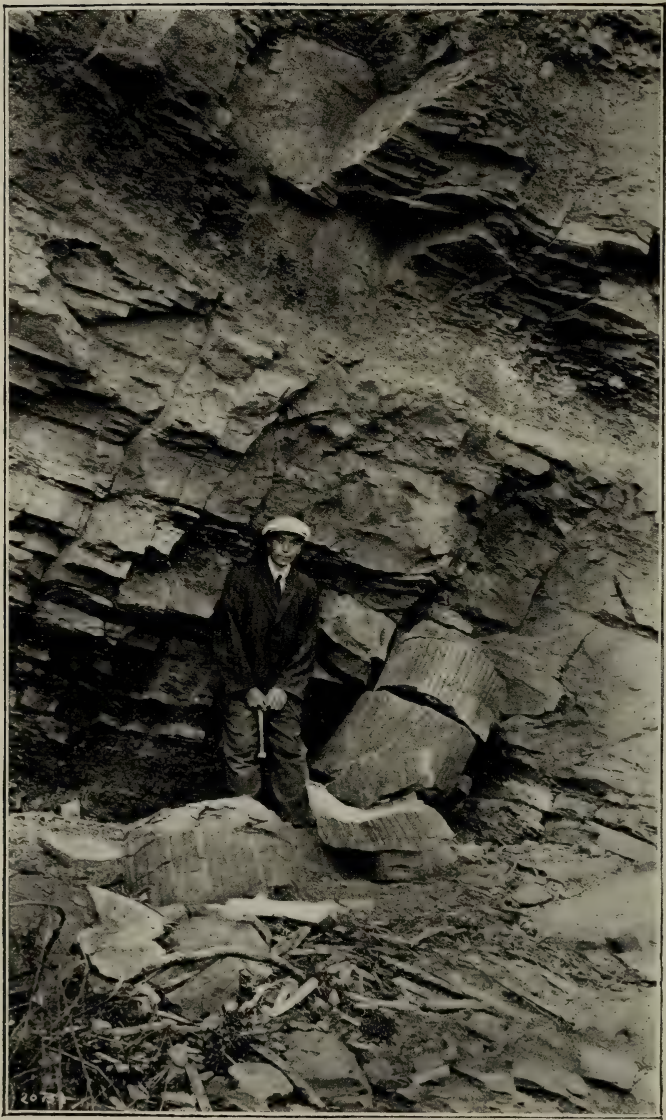
As a consequence of the presence of such abundant organic material much of the ferric iron contained in the sandstones and shales has been reduced to a more soluble salt. This process has been accompanied by a leaching action and deprivation of iron from these beds, which has been supplemented by concentration and redeposition of the iron in the shales in the form of argillaceous hydrated carbonate (ironstone) concretions. The above characters of this formation are illustrated in the first rocks encountered at the high cliff. The first zone of evenly-bedded red shales has associated with it the first coal group, which consists of three minute seams of coal or coaly matter, each less than one inch in thickness, but each underlain by a distinct *Stigmaria* underclay. The regularity of these beds is abruptly and unevenly terminated above by the succeeding

10 feet of reddish grey ill-sorted sandstone, but the latter passes up into a second zone, 46 feet in thickness, of evenly-bedded, red shales without coals, which is likewise cut off by 9 feet of greenish grey coarse sandstone. The succeeding third zone of regular strata includes an interesting and characteristic coal group, where the coals are intimately associated with thin beds of black bituminous fossiliferous limestone. One of these coals has a floor of this dirty limestone, and although the characters of the limestone floor would not seem to furnish a good forest soil, yet nevertheless, this limestone has in it abundant Stigmaria with the attached radiating rootlets, again furnishing evidence of the formation of this coal *in situ*. The upper limestones in the roof carry crushed pelecypod shells of genus *Anthracomya* associated with a tubicular annelid shell, *Spirorbis carbonarius* Dawson, Leperditian ostracods including *Cythere* and fish scales. This coal group like many of the following provides few plant remains. Dawson states however that the coal itself has Cordaites and vascular bundles of ferns associated with vascular tissue of Sigillariæ.

The succeeding 40 feet or so in this group is mainly grey shales containing ironstone balls, and with subordinate carbonaceous seams carrying a fauna similar to the above. Three erect trees, poorly preserved, with coaly streaks marking traces of the old roots, were observed here in the summer of 1912, embedded in the shales but penetrating the coarsely-bedded sandstone above. Several upright Calamites were also noted arising from the base of the sandstone bed. The succeeding strata may be similarly marked out for convenience into zones as the contrast between the regularly bedded strata of the coal and shale zones and the irregular and cross-bedded sandstone zones is usually quite marked.

Erect trees—The number of erect trees to be seen in the following rocks varies of course from year to year with the seasonal wearing back of the cliffs. Their abundant occurrence and position perpendicular to the bedding, is alone good evidence that they are preserved in the position of their growth, *i.e.*, *in situ*.

On close examination it will be seen that in almost every case where the roots are absent, the trunks are abruptly terminated downward either by a coal seam or by a thin seam of carbonaceous shale. The cases indeed are very



An upright fossil tree. Joggins, N.S.

few in which the rhizomes or roots are preserved, but apparently in every case where the trunks stand in shale independently of a coaly seam, some traces of the roots may be seen. Several of such have been observed, where in each case the trunk was attached to roots (rhizomes) of *Stigmaria ficoides* aspect. As the great majority of the trees are sandstone or mudstone casts replacing the interior, only the markings of the deeper cortical surfaces are reproduced as surface markings on the casts. The bark itself, however, is frequently preserved as a coaly coating which may show imperfectly the internal cellular structure. Dawson has carefully worked out the structures of these trees and accompanying flora, and has stated that the greater number of the erect stumps preserved at the Joggins are *Sigillariæ* which have also contributed very largely to the formation of the coals. In fact all of these Joggins coals show unequivocal evidence of *Stigmaria* in their underclays, with the exception of a few thin shaly beds which are filled with drifted leaves. Every underlcay or soil bed, however, does not necessarily bear a coal seam above it.

Dawson has enumerated five species of *Sigillariæ* from the Joggins of which *S. brownii* Dawson, and *S. elegans* Brongniart are the two commonest. The roots of the *Sigillariæ*, or *Stigmariæ*, are the most abundant fossils in the sections but seemingly they are not readily determined specifically, and the greater number are included under the species *Stigmariæ ficoides*.

Associated with these standing forests of *Sigillariæ* are those of *Calamites*, but, whereas the former are embedded at their base in the argillaceous shales, the Calamite brakes terminate most commonly in the arenaceous beds. At the Joggins seven species have been recognized, of which *C. suckovi* Bron. and *C. cistii* Bron. are the most prevalent.

The remaining type of tree standing in an erect position is preserved as pillars of coaly matter or of mineral charcoal, occasionally calcified, which do not show external marking but whose microscopic structure has determined them to be coniferous (Dawson), and which therefore probably represent remains of *Cordaites*. These are rarely seen except in the upper portions of the Joggins formation and in the following Shulie formation.

Flora of the Joggins Section—The remaining flora of the Joggins formation is a drifted one, and for a coal region

is noticeably meager. The Lycopods are much less abundant than Sigillariæ, and are represented only by six identified species of which *Lepidodendron rimosum* Dn., *L. elegans* Dn., and *L. pictoense* Dn., are the most common. There are in addition several species of the related *Lepidophloios* of which might be mentioned *L. acadianus* Dn., *L. parvus* Dn., and *L. prominulus* Dn. Moreover detached Lepidodendroid axes, assigned to the genus *Ulodendron* occur, as well as the detached Lepidodendroid leaves known as *Lepidophyllum*, and fertile shoots or strobile classified as *Sporangites*. The great group of Pteridosperms is next in importance, but is seemingly remarkably deficient in representative species. They include *Alethopteris tonchitica* Sternb. *Sphenopteris latifolia* Bron., *Pecopteris lonchitica* Dn., *Cyclopteris* sp., including seeds doubtfully referred here, e.g., species of *Trigonocarpum*. The additional filicales *Caulopteris* (*Psaronius*) sp., *Megaphyton* (*Psaronius*) *humile* Dn., and *M. magnificum* Dn., may be representatives of the true ferns.

From the beginning of the cliff to the old wharf at the Hardscrabble coal seams, little plant material will be seen, but from the wharf to beyond the Joggins Coal mine, the material is more abundantly found. A nearly complete list of the identified species of the flora and fauna is appended at the close of this account.

Fauna of the Joggins formation—The invertebrate remains are confined almost exclusively to the thin beds of limestone and carbonaceous shales, which probably represent the consolidated mucks of stagnate lakes or lagoons which occurred in the marshy flats. The chief organic remains are crushed shells of *Anthracomyas* or *Naiadites*, of which several species may be recognized, and of smooth Leperditoid ostracods assigned by Dawson to the genera *Cythere* and *Bairdia*. Associated with these remains are the excrement, scales, spines and occasionally the teeth of fish. Of the shark-like types there occur the skins and teeth of *Ctenoptychius cristatus* Dn., *Diplodus* sp., *Gyracanthus duplicatus* Dn., of the Crossopterygian and Chondrostean ganoids, scales of *Rhizodus*, and *Palæoniscus*; while the Dipnoi may be represented by teeth of the genera *Conchodus*.

In common association with the above remains, but especially in attachment to the drifted plant debris, are

found abundant coiled annelid tubes of the species *Spirorbis carbonarius* Dn.

The greatest interest in the Joggins fauna has, however, been directed to the land vertebrate remains which are found in the basal carbonaceous deposits and always in the upright Sigillariæ tree stumps. These all belong to the Stegocephalian amphibians, and are comprised under three main genera, *Dendrerpeton*. *Hylonomus* and *Hylerpeton*. An interesting associate with these forms is the delicate land snail shell, *Pupa vetusta* Dn., which likewise occurs in a few of the shale soils in company with another land shell, *Zonites priscus*, Carpenter. Within the strata proper no amphibian remains have been found with the exception of footprints referred to *Dendrerpeton*, and the single vertebra of *Eosaurus acadianus* Marsh, which was discovered by Marsh west of the coal mine near McCarren brook.

UPPER PART OF SECTION: McCARREN BROOK WESTWARD.

Between McCarren brook and Ragged Reef point, sandstones become again dominant, and the coal groups, although 22 in number, are of very minor importance, but interesting in the fact that they are all accompanied with Stigmarian undersoils. Beds of limestone are entirely lacking in this part of the formation, and in general the effects of swampy conditions are much less evident. Thus the shale zones are prevailingly red in colour, and almost lacking in organic remains with the exception of traces of small rootlets, suggesting conditions of thorough oxidation as well as dessication upon the original mud flats. Erect trees are here rare and the vegetation in general is much more scanty. On the other hand, channelling action of the sandstones and sudden lateral replacements are more conspicuous than before, though evidences of strong current action are not so prevalent as in the succeeding Shulie formation.

Post-Joggins uplift and erosion—The peculiarities of the succeeding Shulie formation are the emphasizing features of strong current action. The beds are dominantly coarse or conglomeratic, and the greater percentage of the pebble content may be readily traced by lithological comparison to its source in a Cobequid upland. Furthermore, the size of the individual pebbles increases towards the

old land. For, whereas the pebbles north of Shulie are in general less than 2 inches in diameter, those in the Apple River conglomerate frequently exceed 12 inches. The presence of a considerable percentage of sandstone and shale pebbles of Pennsylvanian aspect is additional evidence in support of a renewed activity of erosion in the Cobequid area in Upper Pennsylvanian time. But corroborative evidence is also found in the structures of the beds themselves, not only in their unsorted and uneven characters, but in the appearance of the bedding plane of the pebbly sandstones or conglomerates. These show a markedly uneven surface in the presence of great ripples or more properly crests and hollows of a flow and plunge structure. The distance from crest to crest frequently exceeds 10 feet (3 m.) while the furrows may be several feet in depth.

As some beds of the Joggins formation have been stated to have passed over at least a portion of the Cobequids it seems necessary to explain these phenomena by a renewed uplift and erosion of the Cobequid area in post-Joggins time. The continuity of the sedimentation in the central areas of the Cumberland basin seems not to have been disturbed, but an unconformity or disconformity, representing a great time interval, must exist in the borderland of the Cobequids at Spicer's cove as apparently only the basal members of the Joggins formation are there preserved.

Shulie formation.—The main characters of the Shulie formation have been stated above. The flora is meagerly represented by large calcified drift trunks of *Dadoxylon materiarium* Dn., and of drift fragments of *Calamites suckovi* Bron., *C. cistii* Bran., *Calamodendron approximatum* Dn., *Lepidodendron undulatum* Gutbier, *Lepidophloios parvus* Dn., *Lepidophyllum lanceolatum* Lindley and Hutton, *L. trinerve* Dn., erect *Calamites*, erect *Sigillariæ?*, erect conifers (*Dadoxylon?*), *Sphenopteris hymemophylloides* Bron., *Alethopteris lonchitica* (Sternb.), *Cyclopteris heterophylla?* Dn., *Beinertia goepperti* Dn.

The above flora is, according to Dawson, distinct in assemblage of forms from the preceding floras of the Boss Point and Joggins formations, though still retaining persistent types, such as *Alethopteris lonchitica* (Sternb.), *Calamites suckovi* Bron., and *C. cistii* Bron. It suggests, however, as stated by Dawson, Upper Pennsylvanian time, and not Permian, as *Lepidodendra* and *Sigillaria* still hold a prominent position.

JOGGINS FAUNA.

Annelida
- *Spirobis carbonarius* Dawson.

Pelecypoda
- *Anthracomya elongata* Dawson.
- *A. laevis* Dawson.
- *A. ovalis* Dawson.
- *Naiadites carbonarius* Dawson.
- *N. longus* Dawson.

Gastropoda
- *Pupa vetusta* Dawson.
- *Zonites* (*Conulis*) *priscus* Carpenter.

Crustacea
- Ostracoda
  - *Bairdia*
  - *Cythere*
- Myriopoda?
  - *Xylobius sigillariae* Dawson
- Amphipoda?
  - *Diplostylus dawsoni* Salter.
- Merostomata
  - *Eurypterus*? DeKay.

Pisces
- Elasmobranchii
  - *Ctenoptychius cristatus* Dawson.
  - *Diplodus.*
  - *Gyracanthus duplicatus* Dawson.
  - *Psammodus.*
- Dipnoi
  - *Conchodus*
- Crossopterygii
  - *Rhizodus.*
- Chondrostei.
  - *Palaeoniscus.*

Amphibia (Stegocephali)
- Temnospondyli
  - *Dendrerpeton acadianum* Owen.
  - *D. oweni* Dawson.
  - Dendrerpeton? footprints.
- Microsauria
  - *Hylerpeton dawsoni* Owen.
  - *Hylonomus aciedentatus* Dawson.
  - *H. lyelli* Dawson.
  - *H. wymani* Dawson.
- Stereospondyla
  - *Eosaurus acadianus* Marsh.

JOGGINS FLORA.

Pteridophyta (vascular cryptogams)
Equisetales
Calamites cannaeformis Schlotheim.
C. cistii Brongniart.
C. nodosus Schlotheim.
C. nova-scoticus Dawsom.
C. pachyderma Brongniart.
C. suckowi Brongniart.
Calamodendron approximatum Brongniart.
Detached foliage and leaves of Calamites.
Calamocladus (*Asterophyllites*).
Annularia.
Roots of Calamites?
Pinnularia ramosissima Dawson.
Sphenophyllales
Sphenophyllum schlotheimii Brongniart.
Lycopodiales
Lepidodendron aculeatum Sternberg.
L. dichotomum Sternberg.
L. elegans Brongniart.
L. pictoense Dawson.
L. rimosum Sternberg.
L. undulatum Gutbier.
Lepidophloios acadianus Dawson.
L. parvus Dawson.
L. platystigma Dawson.
L. prominens Dawson.
Lepidodendroid axes.
Uloderdron of *majum* Lindley & Hutton.
U. cf. *minum* Lidldey & Hutton.
Detached leaves of Lepidodendra.
Lepidophyllum.
Fertile shoots or strobile of Lepidodendra.
Sporangites glaber Dawson.
S. papillatus Dawson.
Sigillaria brownii Dawson.
S. catenoides Dawson.
S. elegans Brongniart.
S. schlotheimana Brongniart.
S. scutellata Brongniart.
Sigillaria leaves.
Sigillaria rhizomes or roots.
Stigmaria ficoides Brongniart.

Filicales (chiefly Pteridospermae).
Alethopteris lonchitica Sternberg.
Caulopteris (*Psaronius*).
Cyclopteris.
Megaphyton (*Psaronius*) *humile* Dawson.
M. magnificum Dawson.
Pecopteris lonchitica Dawson.
Sphenopteris latifolia Brongniart.
Seeds of Pteridospermae?
Trignoncarpum avellanum Dawson.
T. intermedium Dawson.
T. minum Dawson.
T. sigillariae Dawsom.
Cordaitales.
Araucarites (*Dadoxylon*) *gracilis* Dawson.
Cordaites borassifolius Sternberg.
Dadoxylon (*Araucarioxylon*) *annulatum* Dawson.
D. materianum Dawson.
Pith casts of Cordaites.
Sternbergia artis Dawson.
Seeds of Cordaitales.
Rhabdocarpus Goeppert and Bergeron.
Fertile stems of Cordaitales?
Antholites Brongniart.
Cardiocarpum fluitans Dawson.

INDUSTRIAL NOTES.

The main coal seams were worked at the Joggins as early as 1826, by shaft and horse-gins, but previous to 1854 the total production was only 7,700 Newcastle chaldrons (a chaldron = 72 bushels).

The Joggins mine, at present, is owned and operated by the Maritime Coal Railway and Power Company, Ltd. The seam in the Joggins mine is 3 feet 6 inches (1·06 m.) in thickness. The slopes pitch about 17° at an angle slightly less than that of the seam, and at present are 3,600 feet (1,096 m.) from the surface to the face of sinking. The total output for 1911 was 149,670 tons. In 1912 the output was 600 long tons per day.

The same company owns and operates in the same field the Minudie mine, Black Diamond mine, Maple Leaf and Chignecto mines, which together produced 71,315 tons

in the year 1911. In addition, the Kimberley mine is owned and operated by the Minudie Coal Company.

No definite correlations have yet been made of the seams worked in these various collieries, although it is probable that some are equivalents of the Hardscrabble and overlying seams. The dips of the coals increase inland from 19° south at the Joggins to 40° south at the old Styles mines, 12 miles (19·3 km.) inland. Beyond this the basin is apparently interrupted by transverse folding and faulting.

About 6 miles (9·6 km.) south of the Styles area, in the southern limb of the Cumberland synclinorium, there is situated a coal basin known as the Springhill basin, which embraces seams of greater economic importance. Of these, three are worked which are respectively 5 feet 6 inches (1·7 m.), 8 feet 4 inches (2·5 m.), and 10 feet 6 inches to 4 feet 2 inches (3·2 m. to 1·3 m.) in thickness. The dips vary from 20° to 80° westerly. The precise relation of this basin to that of the Joggins is still one of speculation, although the measures undoubtedly belong to the Joggins formation.

BIBLIOGRAPHY.

Dawson, J. W...... Acadian Geology.

Fletcher, Hugh..... A section of the Carboniferous Rocks in Cumberland County, N.S., Proc. and Trans. Nova Scotian Inst. of Sci., Vol. XI, part 3, pp. 417-550, 1908.

Logan W. E....... Geol. Surv. Can., Report of Progress, 1845.

ANNOTATED GUIDE.

MACCAN JUNCTION TO MONCTON.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

Maccan Junction— Alt. 31 ft. (9·4 m.). From Maccan Junction the Intercolonial railway runs northward following for some distance the eastern side of Maccan river. About ½

Miles and Kilometres.

mile (0·8 km.) beyond Maccan Junction, the railway crosses the northern boundary of the Productive Coal Measures and enters a narrow belt of Millstone Grit beds which dip beneath coal measures. Where traversed by the railway, this band of Millstone Grit has a width of about $\frac{3}{4}$ mile (1·2 km.). The country traversed is low. To the west are visible the highlands on the New Brunswick shore of the Bay of Fundy, distant about 18 miles (28 km.). The high. detached hill is Shepody mountain composed of lower Carboniferous strata. The continuous, somewhat lower upland beyond Shepody mountain, is Caledonia mountain which stretches westward for many miles parallel with the shores of the Bay of Fundy and is formed chiefly of Pre-Cambrian strata.

The Millstone Grit strata are succeeded on the north by a wide area of the Carboniferous Limestone series in which the strata dip southward at angles of 20° to 40°. These measures where traversed by the railway occupy a belt about $3\frac{3}{4}$ miles (6 km.) wide. Towards the northern edge of this belt, the railway passes close to a gypsum quarry, visible on the western side of the railway.

About 5 miles (8 km.) beyond Maccan Junction, the railway enters a broad band of Permo-Carboniferous strata stretching westward from the head of the Bay of Fundy to the shores of Northumberland strait. These measures overlap the Carboniferous Limestone series on the south.

8 m. 12·9 km. **Amherst**—Alt. 63 ft. (19·2 m.). The very low country around Amherst is underlain by gently dipping reddish sandstones and shales of Permo-Carboniferous age. These measures extend northeastward to Cumberland strait, distant about 20 miles (32 km.). The tract of country between the head of the Bay of Fundy and the Gulf of St. Lawrence is everywhere low, probably nowhere reaching an altitude greater than 100 feet (30 m.).

Miles and Kilometres.

From Amherst, the railway runs in a general westerly course and approaches close to the head of the Bay of Fundy. About 4 miles (6·4 km.) beyond Amherst the railway enters a narrow belt of country believed to be underlain by Millstone Grit. This belt is about 1½ miles (2·4 km.) wide and extends to the northeast where it is marked by a low ridge. This band of Millstone Grit extends in a westward direction across the head of the Bay of Fundy and there rises in a marked ridge.

14·2 m. 22·8 km. **Aulac Station**—Alt. 26 ft. (7·9. m.). Aulac station is situated near the northwestern margin of the presumably anticlinal band of Millstone Grit. The low country beyond and the rising ground towards the west are occupied by reddish Permo-Carboniferous strata dipping over the greater part of the area to the southwest at angles of 15° to 30°. Between Aulac station and Sackville, the railway passes around the extreme head of the Bay of Fundy.

17·9 m. 28·8 km. **Sackville Station**—Alt. 26 ft. (7·9 km.). The low country about Sackville presumably lies on the axis of a synclinal fold in Permo-Carboniferous strata. These measures extend for about 1½ miles (2·4 km.) to the south to the foot of a ridge of northward-dipping Millstone Grit beds. To the northwest of Sackville, the Permo-Carboniferous strata dip southwards at angles of 20° to 30° and rise in a series of ridges 400 to 600 feet (120 m. to 180 m.) high. On the top of this upland, Millstone Girt strata appear from beneath the Permo-Carboniferous without any evidence of an unconformity.

From Sackville the railway runs westerly up a valley near the southern margin of the Permo-Carboniferous area and for some miles continues to ascend. Beyond the head of the valley the railway crosses a divide with an altitude of 234 feet (71·3 m.), and a short distance beyond crosses the northern boundary of the Permo-Carboniferous area and enters a district occupied by Millstone Grit strata. As the railway continues to descend, it enters and follows a

Miles and Kilometres.

pronounced valley which eventually turns to the west and joins the broad valley of Memramcook river. Before entering this main valley, the railway passes through a long cutting of grey Millstone Grit sandstone dipping southward at an angle of 20°.

On entering the Memramcook valley, the railway bends to the north and traverses the low diked land bordering the river. On the opposite shore of the river rises a rounded ridge of Millstone Grit grey sandstone and quartz conglomerate dipping southward at low angles. Before reaching Dorchester station the railway passes out of the Millstone Grit area and enters one occupied by a coarse red conglomerate of lower Carboniferous age. The two formations dip to the southward at angles of 10° to 25° and appear to be conformable though they are presumably of widely different ages.

29·3 m. **Dorchester Station**—Alt. 27 ft. (8·2 m.).
47·1 km. Beyond Dorchester station the rising ground on the east is occupied by red conglomerates and sandstones capped on the summits of the ridges by the grey strata of the Millstone Grit. Approaching Upper Dorchester station, the low-lying ground immediately adjacent to the railway is underlain by strata of the Albert series which have been correlated with the Horton series of Nova Scotia, and are considered to be of early Carboniferous age.

32 m. **Upper Dorchester Station**—Alt. 27 ft.
51·5 km. (8·2 m.). On the western side of Memramcook river, just above the highway bridge at Upper Dorchester, are low cliffs of the Albert series which at this point lie in a flat anticline. The strata in these low cliffs are dark shales or "oil-shales" very rich in hydro-carbons. The lower slopes of the rising ground west of the river are occupied by gently dipping red sandstones and grits while the summit of the ridge is formed of the grey sandstone and quartz conglomerate of the Millstone Grit. On the opposite side of the ridge somewhat similar strata occur overlying the Albert series which,

Miles and Kilometres.

as exposed in several detached areas, dip with high angles in various directions.

North of Upper Dorchester station, the railway again enters an area underlain by Albert strata and these are capped by coarse grey Millstone Grit conglomerate forming a low ridge rising just east of the railway.

34·9 m. 56·2 km. **College Bridge Station**—Alt. 32 ft. (9·7 m.). In the vicinity of College Bridge station the Albert series underlies a very limited area on the east side of the river. On the west side of the river, this series with its "oil-shales" is more fully developed over a band about 1 mile (1·6 km.) wide which extends in a northwesterly direction for about 6 miles (9·6 km.) to the banks of the Petitcodiac river, opposite the Stony Creek oil and gas field.

A short distance beyond College Bridge station, the railway again enters an area underlain by lower Carboniferous strata—red shales, sandstones and conglomerates. These measures occupy the lower slopes of the ridges bounding the Memramcook valley but the summits of these hills are capped by nearly horizontal grey, Millstone Grit sandstones and conglomerates.

As the railway follows northward up the Memramcook river, the valley gradually contracts. About 4½ miles (7·2 km.) beyond College Bridge station, the railway passes through a series of cuttings in granite. These exposures belong to an area of granite having a maximum diameter of about ½ mile (0·8 km.) and which apparently represents an island-like projection of the floor on which the Carboniferous measures were deposited.

41·5 m. 66·8 km. **Calhoun Station**—Alt. 54 ft. (16·4 m.). Beyond Calhoun station the valley of Memramcook river becomes very shallow and gradually dies away. The surrounding country is very even in character and is presumed to be underlain by nearly horizontal strata of Millstone Grit age. Four and a half miles (7·2 m.) beyond Calhoun station the railway crosses a

Miles and Kilometres.	
	low summit (altitude 180 feet or 54·8 m.) and commences to descend to the valley of Petitcodiac river.
48·6 m. 78·2 km.	**Painsec Junction**—Alt. 149 ft. (45·4 m.). The gently rolling country to the west of Painsec Junction is underlain by nearly horizontal red shales and sandstones, interbedded with grey sandstones, all of Millstone Grit age. From several points along the railway a comparatively high ridge is visible to the north. This ridge is formed in part of sedimentary strata and possibly in part of igneous rocks. It is probable that the Albert series is represented in this ridge but it is not improbable that the strata are chiefly of pre-Carboniferous age.
56 m. 90·1 km.	**Moncton**—Alt. 50 ft. (15·2 m.). Moncton is situated on the north side of Petitcodiac river where this river after flowing for a number of miles in an easterly direction, abruptly turns and pursues a southerly course as far as its mouth where it empties into the Bay of Fundy.

MONCTON—ALBERT MINES.*

(G. A. Young.)

INTRODUCTION.

Moncton is situated near the southern margin of the great Carboniferous area of New Brunswick which in the eastern part of the province, stretches from Chaleur bay on the north to the head of the Bay of Fundy on the south, a distance of about 150 miles (240 km.). The Carboniferous area of New Brunswick extends over approximately 10,000 square miles (26,000 sq. km.) and over by far the greater part of this large area the strata are nearly flat-lying and, customarily, are considered to be of Millstone Grit age. Along the southern margin of the area older divisions of the Carboniferous are exposed and, in places, are folded and faulted.

*See Map—Moncton—Albert Mines.

The city of Moncton lies about 20 miles (30 km.) north of the eastern end of Caledonia mountain, an upland area largely underlain by pre-Carboniferous igneous and sedimentary rocks that extend southwesterly along the Bay of Fundy coast and mark the southern boundary of the Carboniferous area. Over considerable portions of Caledonia mountain, the surface is comparatively level with a general altitude of above 1,000 feet (300 m.). In the vicinity of Moncton, the country is low and gently rolling, and in only a few places rises higher than 200 to 300 feet (60 m. to 90 m.) above the sea. The lowland area about Moncton and the upland area of Caledonia mountain merge into one another, though when the country is viewed from a vantage point, there is every appearance of a sharp boundary between the two areas.

Moncton is situated near the southern margin of the area of grey and red sandstones and shales of Millstone Grit age which stretches westward and northward like a great mantle over a large portion of New Brunswick. The Millstone Grit beds extend southward past Moncton over the area of gradually rising country which merges into the upland of Caledonia mountain. Along the borders of Caledonia mountain and stretching northward and eastward from it, are deep-set valleys and in and along these valleys are exposed older Carboniferous measures outcropping from beneath the Millstone Grit beds which on the north crown the ridges and higher spurs that project finger-like towards Caledonia mountain. The underlying, older Carboniferous strata include representatives of the Carboniferous Limestone series, and of the Albert series which have been correlated with the Horton series of Nova Scotia, and are considered to be of very early Carboniferous age.

The Millstone Grit strata lie horizontally or with very low angles of dip; in places the underlying Carboniferous strata are as little disturbed, while in other places in the same district they are faulted and tilted at high angles. There is thus abundant evidence of a pronounced unconformity between the Millstone Grit and the underlying divisions of the Carboniferous, and there is also direct evidence of the existence of unconformities between some of the older divisions.

The Millstone Grit beds and the underlying Carboniferous formations extend southward around the eastern end of

A1.

Geological Survey, Canada

Moncton-Albert Mines

Miles

1 0 1 2 3 4 5

Kilometres

1 0 1 2 3 4 5 6 7

the pre-Carboniferous area of Caledonia mountain and eastward into Nova Scotia where the New Brunswick Carboniferous area merges into that of the Carboniferous basin, the general characters of which are so well displayed in the Joggins section. In the relatively elevated country which extends eastward from the end of the Caledonia upland, the Millstone Grit strata gradually lose the nearly horizontal attitude so characteristic of their general development over so large a portion of New Brunswick, and in places are inclined at angles of from 30° to 45° and presumably traversed by faults. On the other hand, the underlying Carboniferous measures in their extension southward and eastward into Nova Scotia, are less and less folded and faulted. As a result of these progressive changes, the evidences of the unconformities in the Carboniferous section so plainly displayed to the south of Moncton, largely disappear in the Joggins section and in other districts of Nova Scotia, and the Carboniferous series in such places appears to have always been folded and otherwise deformed as a unit.

The districts bordering Caledonia mountain and extending eastward along the continuation of the axis of this upland, are, as indicated above, favourable places in which to determine and fix some of the revolutionary periods of Carboniferous time. Unfortunately, however, this has not yet been accomplished. On the accompanying geological sketch map of the district lying immediately south of Moncton and east of Petitcodiac river, the Carboniferous strata have been provisionally mapped in three divisions, namely,—Millstone Grit, Intermediate group and Albert series. It is not improbable that in the Intermediate group are placed certain measures that should be classed with the Millstone Grit, and others that should have been assigned to the Albert series.

In the general district to the south of Moncton, outlined on the accompanying map, there is a very distinctive division of the Millstone Grit consisting of a quartz conglomerate overlain by a quartzose sandstone. Both types of rock are light coloured, weathering yellow. The conglomerate is usually crowded with smooth, rounded pebbles of white and variously tinted quartz lying in a sandy, in part calcareous, base. This conglomerate with its distinctive characters, and the overlying sandstones, occur in neighbouring districts and the same conglomerate, or a

very similar one, has been described as being present in many places over the wide extent of the Carboniferous area of the Maritime Provinces.

In the vicinity of Hillsborough and Albert Mines, these light coloured conglomerates and sandstones are the youngest Carboniferous strata present; the areas occupied by them are those which on the accompanying map, have been coloured as being underlain by the Millstone Grit and over these areas the strata are horizontal or only very gently inclined. Northward of the vaguely defined boundary of these pale coloured, quartzose sandstones and conglomerates, the low country towards Moncton is floored by nearly horizontal reddish sandstones, shales and red, argillaceous limestones. In a few places the pale coloured, Millstone Grit sandstone and conglomerate outcrop and in such places appear to conformably overlie or to be interbedded with the red strata which have customarily been assigned to the Millstone Grit. Along the southern boundary of the main area of the pale coloured Millstone Grit strata as defined on the accompanying map, measures outcrop from beneath these distinctive beds which have been placed in the so-called Intermediate group but which probably in part belong to the Millstone Grit group. Such strata, for instance occur in the valley of Stony creek and there consist of quartz conglomerate, coarse and fine, light-coloured sandstone, and red and green argillaceous and calcareous shales.

The greatest thickness of the pale coloured, Millstone Grit conglomerate and sandstone does not exceed a few hundred feet. The reddish, underlying strata presumed to belong to the same group, may be somewhat thicker but the strata of the whole Millstone Grit group as developed in the neighborhood of Moncton and Hillborough, does not anywhere attain a thickness comparable with that found in various districts of Nova Scotia. In general, the Millstone Grit strata appear to form a comparatively thin mantle resting on and covering the variously disturbed and eroded members of the older divisions of the Carboniferous. In places, however, in this and adjoining districts, the Millstone Grit beds appear to conformably succeed different divisions of the earlier groups without any plainly marked indications of the unconformity that is known to exist below the horizon of the Millstone Grit.

The strata of the area of the so-called Intermediate group indicated on the accompanying map, may, as already stated belong in part to the Millstone Grit. What appears to be the lowest member of the Intermediate group holds as a characteristic member a very considerable thickness of red strata that in composition vary from an argillite to a limestone, are generally of a bright, brick-red colour but in many places are splotched or banded with green. With these rocks are associated reddish sandstones and conglomerates and, perhaps, grey and dark grey limestones and siliceous beds.

A second division of the Intermediate group, younger than the above, consists of coarse, heavily bedded conglomerates and sandstones overlain by dark grey thinly bedded limestones which in places, as near Hillsborough, are capped by a considerable volume of anhydrite and gypsum.

A third, still younger member of the Intermediate group is made up essentially of red conglomerates and sandstones succeeded by red and green argillites and argillaceous limestones.

The total thickness of these three divisions of the "Intermediate group" must surpass several thousand feet. The strata in places lie with high angles of dip; in other localities they are nearly horizontal, and in such cases different divisions may appear to succeed one another conformably, as if without a break, although there is indirect evidence to indicate that prior to the deposition of each succeeding division, the strata of the immediately underlying division had been eroded in no inconsiderable degree.

The Albert series is the oldest of the Carboniferous system in the district. This series consists of a group of thinly bedded, usually dark coloured slates, calcareous slates, limestones and sandstones. Interbedded with these, whether or not at more than one general horizon has not yet been determined, are slates relatively rich in hydrocarbons and of a distinctive appearance. These, so-called, oil-shales when retorted yield varying amounts of crude oil and nitrogen—about 27 to 56 imperial gallons of crude oil, and about 30 to 112 pounds of ammonium sulphate per ton [**3**, part I, p. 17]. In these oil shales and associated beds, in places, are numerous remains of fishes of the genus Palaeoniscus. From the Albert series as developed in the

neighborhood of Albert Mines, the following species have been described. [**6**].

Rhadinichthys alberti.
Elonichthys browni.
E. elegantulus.
E. ellsi (Lambe).

Though by some geologists it has been claimed that the Albert series and the correlated Horton series of Nova Scotia are of Devonian age yet the palæontological evidence indicates that they are of Carboniferous age as pointed out by Lambe [**6**] in the following words.

"There is a great similarity between the fishes of Albert mine......and those described by Dr. Ramsay Traquair from the Calciferous Sandstone series of Scotland; they belong to the same genera, but differ as to species. The genera of Palaeoniscidae; *Rhadinichthys*, *Elonichthys*, and *Canobius*......have been considered to be typical of the Carboniferous age".

From the Albert series have been recovered several species of plants. These include "*Aneimites acadiens* and *Lepidodendron corrugatum*, the characteristic and omnipresent species of the Horton group, to which the Albert series belongs."*

The strata of the Albert series are exposed in the vicinity of Albert Mines and at other localities to the east and west. In some of these places the strata are comparatively undisturbed and lie with low angles of dip ranging in value between 5° and 30°. In the Albert Mines area, however, the strata form a rather tightly compressed anticlinal fold, and in places are vertical. At this locality they are unconformably overlain by division two of the Intermediate group.

The Albert series is of especial importance since it is from the sandstone members of this series that the petroleum and natural gas of the Stony Creek field (situated a few miles north of Hillsborough) are derived. The Albert series, with the same general characters as at Albert Mines, is exposed over a few detached areas extending east from Albert Mines for about 15 miles (25 km.). The same strata outcrop at intervals for about 25 miles (40 km.) to the west of Albert Mines and there occur along the northern slopes of Caledonia mountain. The Albert series has been

*From personal communication from David White, U. S. G. S., Washington, D. C.

traced still further westward and the late R. W. Ells has recorded his belief [**3**, part II, pp. 10-21], that the Albert series progressively changes in character as followed in a westerly direction, and that near St. John, on Kennebecasis island it is represented by coarse grey sandstones.

The oldest strata, in the district to the south of Moncton, are those forming Caledonia mountain. Over this upland area, the rocks are largely of igneous origin, and at many localities have a schistose structure. The original rock types appear to have been mainly volcanic varieties, both massive and fragmental, and both acid and basic. Plutonic rocks—granite, diorite, etc.—form large bodies in the complex, and true sediments—slates, crystalline limestones, etc.—have been noted at various places. The general assemblage is of pre-Carboniferous age, for most of the rock varieties have furnished pebbles and boulders to the Carboniferous strata. Presumably the greater part of the rock complex of Caledonia mountain is of Pre-Cambrian age but in its western extension towards St. John city, Cambrian rocks and possibly younger strata are involved.

DETAILED DESCRIPTION.

MONCTON TO STONY CREEK OIL FIELD.

Along the highway leading from Moncton southward along the west side of Petitcodiac river to the Stony Creek oil field, there are few outcrops for a number of miles. On the south bank of the Petitcodiac, a short distance below the highway bridge crossing the river at Moncton, red argillite and argillaceous sandstone are exposed at low water. These beds are assumed to belong to the Millstone Grit group and to occur at a horizon below the light coloured quartzose sandstones and conglomerates so widely displayed over the country to the south.

About 3 miles (4·8 km.) south from the bridge at Moncton, the road on the west side of Petitcodiac river crosses Mill Creek. In the bank of the stream, just above the road crossing, is an exposure of nearly horizontal, light coloured sandstone resembling the strata of the higher horizon of the Millstone Grit developed farther south. In the bed of this stream for a considerable distance inland, red argillites, sandstones, and fine grits with grey beds of

the same rocks, outcrop with nearly horizontal attitudes. These measures presumably also belong to the lower division of the Millstone Grit.

No further exposures occur along the river or the road for some distance. About 1 mile (1·6 km.) beyond the crossing of Mill Creek, the road swings away from the shore of the river and runs on the side of a ridge sloping somewhat steeply to the river. This ridge is presumably underlain by the higher division of the Millstone Grit though no rocks outcrop.

On the shore opposite a point on the road about 1 mile (1·6 km.) south of the junction with a branch road leading inland, exposures commence and continue to occur along the shore to within a short distance of the mouth of Stony creek. The most northerly exposures are of pale coloured quartzose sandstones belonging to the upper division of the Millstone Grit. The strata dip to the south at a very low angle. Farther south the strata are horizontal and beyond this, dip at very low angles to the north. Approaching Stony creek, the quartzose conglomerate is brought to the surface by reason of the gentle northward dip and in the cliff faces along this part of the shore, the Millstone Grit conglomerate may be seen to be underlain by about 30 feet (9 m.) of red argillite reposing on red conglomerate. All the strata appear to be conformable and possibly belong to the Millstone Grit group. The boundary between the light coloured strata above and the red beds below, crosses the shore road where the steep descent into the valley of Stony Creek is commenced. This boundary line approximately follows a contour line and swings up the deep valley of Stony creek and returns towards the river higher on the slopes of the ridge lying south of Stony creek. The light coloured strata evidently lie on the northern limb of a very low anticlinal fold or flattened dome.

Where the shore road crosses Stony creek, there are, in the steep south bank of the stream valley, exposures of nearly horizontal, light coloured sandstones and conglomerates. Up the valley of Stony creek, these measures are overlain by green and red banded argillites and argillaceous limestone.

South of the crossing of Stony creek, the shore road enters what may be termed the Stony Creek oil and gas field. The wells are scattered over the top and eastern face of the high ridge fronting on the river.

STONY CREEK OIL AND GAS FIELD.

The present developments of the Stony Creek field are confined to an area about 2 miles (3·2 km.) long by $1\frac{1}{2}$ miles (2·4 km.) broad, fronting on the west bank of Petitcodiac river and lying between Stony creek on the north and Weldon creek on the south. Between the two creeks the land rises rather rapidly from the level of the tidal river to an altitude of 460 feet (140 m.). Of the 23 wells drilled by the Maritime Oilfields Company, 4 are on the steep east front of the hill and the remaining 19 are scattered over the top of the hill.

Along the river front, strata of the Albert series are visible at low water over a stretch of about 2 miles (3·2 km.). At the north end of the section they are overlain by coarse, red conglomerate; proceeding southward, at the first exposures they lie nearly horizontally, beyond this they dip in various directions between south and west, at angles of 10° to 20°. The measures consist of thin-bedded limestones and dark shales with sandstone beds which in places are impregnated with hydro-carbons. The measures apparently lie on the crown of an anticline but there are indications that in places the strata are crumpled and faulted.

The lower slopes of the ridge facing the river to the east and the valley of Weldon creek to the south, are occupied mainly by nearly horizontal coarse red conglomerates and sandstones with some shales. These measures are conformably overlain by the quartz conglomerate and over this, by the light-coloured sandstone of the Millstone Grit. Possibly the lower, red strata belong to the Millstone Grit, but it may yet be proved that they are considerably older. On the north side of the ridge along the valley of Stony creek, the measures underlying the pale-coloured Millstone Grit beds consist of red and green shales, and sandstones, with beds of grey sandstone, quartzose conglomerate, etc. Thus the Albert series outcropping along the eastern base of the hill extends westward under it, as shown by the borings, and is overlain by red strata capped by grey beds. The Albert series is of very early Carboniferous age, the grey beds of mid-Carboniferous age. The exposures indicate, in general, that the measures of all the divisions have relatively gentle dips.

The wells stand at elevations varying between 250 feet and 460 feet above sea-level, and in depth they range from

1,200 to 2,060 feet (365 to 628 m.). After passing through a thickness of overlying formations usually amounting to about 350 feet (107 m.), they enter the Albert series, of which a maximum thickness of 1,800 feet (548 m.) has been penetrated without encountering any signs indicating the approach of the base of the formation.

The strata of the Albert series, as found in the various wells, consist mainly of thinly-bedded, shaly beds, usually black or dark green in colour and varying in composition from argillite to limestone. Besides the shaly strata, fine-grained quartzose sandstones are comparatively common, the number of individual sandstone beds in a single well varying between 3 and 15. In thickness the individual sandstone beds vary from a few feet to 100 feet (30 m.) or more. There is a rather general tendency for the sandstone beds to occur in groups, in a number of instances three such groups separated by intervals of 150 to 350 feet of shales (45 to 106 m.) being encountered in a single well. The aggregate thickness of a single group of sandstones may rise to 180 feet (55 m.), but more often lies between 3 and 90 feet (9 and 27 m.). The individual beds of a group of sandstones may be separated by shaly layers varying in thickness all the way from a few feet to 30 feet (9 m.) or more.

Though slight traces of oil or gas have been found in the shaly beds and, in one instance, in strata overlying the Albert series, the oil and gas are confined, practically, to the sandstone beds in the Albert series. In the case of one well which the drillers recorded as apparently passing through disturbed, broken strata, practically all the sandstones are free from oil or gas. In the producing wells, a small number of sandstone beds do not afford any trace of oil or gas. Usually the number of such dry beds is small in comparison with the total number of sandstone beds in a well; and the dry beds, as a rule, occur towards the top of the well, but such beds are also recorded as occurring beneath others with showings of oil or gas. Usually by far the greater number of the sandstone beds are recorded as at least showing oil or indicating the presence of gas, and in some of the wells, sandstone beds of two different horizons yield large volumes of gas.

In the case of about one-half of the number of the wells, all the sandstone beds (except such as are dry) of each well are recorded on the logs as being either all oil sands or all

gas sands. In the remaining cases, oil and gas sands irregularly alternate or they occur in two groups of which, in some wells, the oil sands form the higher group while in others the gas sands form the higher groups.

In two wells, strong flows of salt water were recorded. In one case the salt water was struck near the bottom of the well, being first met in a 12-foot (3·6 m.) sandstone bed lying 68 feet (20·7 m.) below an oil sand that, with other immediately overlying sands, yielded oil at the rate of 5 barrels per day. In the second instance, after having passed through two sands, both giving indications of oil, and one giving a small show of gas, a salt water sand was struck at a depth of about 810 feet (247 m.). This well was continued to a depth of 1,250 feet (380 m.), and in the additional distance of 440 feet (134 m.) passed through four beds of sandstone with an aggregate thickness of 245 feet (74·5 m.), but which were barren of oil or gas except in the case of the lowest bed which was said to give a "show of gas".

From seven of the wells the total calculated yield of gas, as derived from measurements made with a Pitot tube, was nearly 4,000,000 cubic feet per day, the closed pressure of the individual wells varying from 20 to 200 pounds per square inch. From twelve other wells, varying results were obtained. One well had a closed pressure of 525 pounds, rising in three days time to 610 pounds, and an estimated flow of 3,695,000 cubic feet per day; a second had a closed pressure of 475 pounds and an estimated flow of 8,893,000 cubic feet per day; and a third had a closed pressure of 560 pounds with an estimated capacity of 6,417,000 cubic feet per day. In these three cases, the volume was estimated from observing the rate of rise of pressure at one minute intervals. As regards oil, in the case of one well, 60 barrels accumulated in 20 hours; from another after an interval of 7 days, 87 barrels were pumped; while a third gave an estimated yield of 40 barrels in 25 hours. The above figures have been taken from records of the Maritime Oilfields Company who are developing the field.

STONY CREEK OIL FIELD TO HILLSBOROUGH GYPSUM QUARRIES.

Leaving the Stony Creek oil field, the highway descends the long slope to the valley of Weldon creek, and ascends and crosses the low ridge to the south, on which stands Hillsborough. The strata outcropping on the southern slopes of the ridge facing Weldon creek valley, are red conglomerates with interbedded red shales and sandstones. On the higher slopes, these measures are nearly horizontal, lower down on the valley side they dip both southward and westward at angles of 20° to 50°. Similar measures outcrop in the valley of Weldon creek dipping to the north, though where the highway crosses the creek near its mouth, the strata are nearly horizontal or dip at low angles to the south. Weldon creek valley apparently marks a synclinal axis in the red series and confirms the impression that the general structure of the Stony Creek oil field is anticlinal.

The low, broad ridge on which Hillsborough stands is underlain by red conglomerates with sandstones and shales, forming a general assemblage very similar to that developed in Weldon creek valley. The strata are folded along east and west axes, in places the angles of dip are high—60° to 70°— and presumably the measures are traversed by faults.

The ridge on which Hillsborough stands is bounded on the south by the valley of Quarry creek, which heads to the west in the gypsum quarries. A road leads up this valley to the quarries; the main road continues southward parallel with the river. Along the main or river road there are a few exposures of red conglomerate and the same strata, lying nearly horizontal, are exposed on the eastern slopes of the ridge rising to the south. In this ridge the red conglomerate is directly overlain by grey limestone beds which on the summit of the ridge are capped by gypsum beds. Farther south, apparently the same red conglomerate beds outcrop along the river bank, dipping gently to the south. These red conglomerates outcrop in the steep, cliff-face of Hopewell cape and are there overlain by about 100 feet (30 m.) of red sandstones, above which come 30 feet (9 m.) of red and grey shales capped by heavy beds of grey quartzose conglomerate and sandstone belonging to the Millstone Grit. All the strata appear

conformable and the general succession is very similar to that in the cliffs along the river above Stony creek, 12 miles (19 km.) to the north. The absence of the limestone and gypsum in the cliffs of Hopewell cape and their presence elsewhere intervening between the red conglomerate and the grey strata of the Millstone Grit, is presumptive evidence of the existence of an erosion plane beneath the Millstone Grit. Elsewhere in the general district there is evidence that this erosion was of a very pronounced character; that prior to Millstone Grit time, the older Carboniferous strata were carved into pronounced valleys and during the Millstone Grit period these valleys were filled with reddish sandstones and shales, while over all was laid a mantle of the grey quartzose conglomerates and sandstones.

On both sides of the valley of Quarry creek, along which runs the road leading to the gypsum quarries, are exposures of red conglomerate. The conglomerate strata of the ridge on the south side dip gently to the south and are overlain by grey limestone. The red conglomerate and the limestone beds are exposed on the side of the creek at the northern entrance to the gypsum quarries. Similar limestones outcrop to the west on the northern and western sides of the area of gypsum, and in general fashion, the dips indicate that the gypsum occurs towards the centre of a very shallow syncline probably traversed by a north and south fault situated toward the western edge of the area. On the south the gypsum area is bounded by a high ridge over whose summit the grey Millstone Grit strata outcrop, while between these and the gypsum beds, intervene red sandstones and conglomerates with a maximum thickness of probably not more than 100 feet (30 m.).

THE HILLSBOROUGH GYPSUM DEPOSIT.

(H. E. KRAMM.)

The limestone upon which the gypsum and anhydrite beds rest, have a thickness of approximately 40 feet (12 m.). The gypsum and anhydrite beds have a thickness of about 250 feet (76 m.). The gypsum is the massive crystalline variety. It is usually slightly coloured by some impurities such as oxide of iron, calcium carbonate and organic matter, but absolutely pure gypsum, the variety alabaster, is also found at Hillsborough and mined. Crystals of selenite

imbedded in the solid crystalline gypsum are common near the surface of the deposit. Some of them are 3 to 4 inches (7·5 to 10 m.) in length and are perfectly terminated and easily separated. Satinspar, the fibrous variety, is rare at Hillsborough.

For the origin of the gypsum deposits of New Brunswick and Nova Scotia, Dawson proposed a conversion of calcareous beds by means of sulphuric acid, the acid being derived from igneous rocks and active volcanoes. This theory is an improbable one since there are ,at least in New Brunswick, no extensive bodies of igneous rocks present in the neighborhood of the gypsum deposits. Furthermore the gypsum often exhibits a series of approximately parallel lines of a darker color. These lines represent planes of easy cleavage and are thin films of calcium carbonate. Assuming an origin as proposed by Dawson it would indeed seem strange that sulphuric acid should convert practically the whole mass to gypsum and leave a series of films of calcium carbonate unattacked.

The field evidence obtained by the writer indicates a transformation of the anhydrite into gypsum. Evidence of this is especially abundant at Hillsborough. The gypsum rests upon a bottom of anhydrite and reaches a maximum thickness of perhaps 125 feet (38 m.). The hydration of the anhydrite can be observed in many places, taking place in either of two ways, namely:— (1) Hydration is uniform from the surface towards the centre of the mass and the increase in volume caused by the process breaks and shatters the outer layers. (2) Hydration starts along some crack or fissure which becomes filled by gypsum. The force exerted by the gypsum during its formation, causes the anhydrite to split into a network of fissures along which hydration proceeds and eventually converts the whole mass into gypsum.

It is, however, not likely that the calcium sulphate was originally deposited in the form of anhydrite. The physical chemistry of anhydrite has never been understood. Van't Hoff determined thermodynamically, that anhydrite is deposited in a saturated sodium chloride solution at 36° C. Actually, to the writer's knowledge, this has never been experimentally verified. The claims of geologists for the deposition of calcium sulphate as anhydrite are principally based upon the fact that anhydrite is found in nature, and upon the experiments of Van't Hoff. The first is an idea

which can be disputed; Van't Hoff's results, however, as to soluble anhydrite have been disproven by W. A. Davis* who showed that it is ordinary anhydrite that forms, and not, as Van't Hoff claimed, an anhydrite with entirely different physical properties. This puts the results as to anhydrite into a rather doubtful light. It is certain that anhydrite is not deposited in water at ordinary temperatures and under such conditions as exist at the present day, and it is not deposited at much greater temperature.

On the other hand, gypsum is easily dehydrated at low temperatures. It is much more probable that the calcium sulphate deposits were deposited in the form of gypsum, and that the pressure caused by the enormous layers of sediments which were subsequently piled on top of it partly or wholly dehydrated it. The dehydration of the gypsum is observable at the present day.

ALBERT MINES.

From the western head of the gypsum quarries, a road leads to the valley of Frederick brook and to the area of the Albert series at Albert Mines. Along this road, on the brow of the slope to the valley of Frederick brook, are exposures of grey limestone dipping eastward at angles of 60° to nearly 90°; in places the strata are contorted. Presumably the strata are traversed by a fault. Along the road farther south where it parallels the railway traversing Frederick brook valley, is a low cliff of coarse conglomerate dipping to the east at a low angle. A short distance east, the conglomerate is overlain by the grey limestone, above the limestone occurs red sandstones overlain by the grey beds of the Millstone Grit. No gypsum is known to be present and though it may have been cut out by a fault, it is more probable that the gypsum was removed by erosion prior to the deposition of the Millstone Grit.

The conglomerate exposed in the cliff at the roadside, and in a small cutting along the railway and elsewhere in the neighborhood, is very dark in colour due to the presence of hydro-carbons with which the rock is impregnated. The conglomerate is the ordinary red conglomerate which

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*Jour. Soc. Chem. Ind. Vol. XXVI, 1907, p. 727.

elsewhere occurs underlying the limestone and gypsum beds.

The low area of the valley of the western branches of Frederick brook which extends westward from opposite the cliff of conglomerate on the road side, is occupied by strata of the Albert series. The rising ground on all four sides is underlain by the gently dipping red conglomerate which near the area of the Albert series is, in many places, of a dark grey colour from the presence of hydro-carbons. Though no fragments of the Albert series have been found in the conglomerate of the surrounding area, it seems impossible to escape the conclusion that the surrounding, gently dipping conglomerates unconformably overlie the highly disturbed strata of the Albert series.

The Albert series at Albert Mines outcrops over an area about 1¼ miles (2 km.) long in an east and west direction and having a variable width of from ¼ to ¾ miles (0·4 to 1·2 km.). The strata are comparatively well exposed in the eastern part of the area, along the various branches of Frederick brook. The measures, in general, dip to the south with angles varying from 15° to nearly 90°. On one branch of the brook the crown of an anticlinal fold is visible and it has generally been stated that the measures lie in an anticlinal fold whose axis strikes east and west. The strata as exposed consist chiefly of dark, thinly bedded shales, and thin beds of dark limestones. At certain horizons occur "oil-shales" heavily impregnated with hydro-carbons. Two main varieties of oil-shales are present. In the case of one variety —"curly shales"— the rock is compact, splintery, and the bedding planes in many instances are minutely crenulated. In the case of the second variety—"paper shales"— the beds split into thin, slightly flexible sheets.

The mining operations at one time carried on in this area and the extent of which is indicated by the large dumps, were conducted for the purpose of winning the substance albertite, fragments of which are abundant in the mine dumps. Albertite, by many authorities classed with asphalt and supposed to be a solidified form of petroleum, is a black substance, having a conchoidal fracture and a hardness of about 2 on the ordinary scale of hardness. It is easily fusible and readily ignites in an ordinary flame. It is essentially composed of hydrogen and carbon with about 3 per cent of nitrogen, 2 per cent of

oxygen, and a trace of sulphur. The mineral occurs filling fissures, usually narrow, not only in the Albert series but in younger Carboniferous strata. Most of the reported occurrences of such veins have been within a radius of a few miles from Albert Mines. The only large vein ever discovered was that occurring at Albert Mines. This vein, it is said, was mined over a distance of about ½ mile (0·8 km.). and to a depth of 1,100 feet (330 m.) or more, beyond which it became too narrow to be profitably worked. The vein was nearly vertical and followed an almost straight course along the general direction of the anticlinal axis in the country rock, but varied in width up to 15 feet (4·5 m.) and sent apophyses into the adjoining strata.

Regarding the origin of the albertite, "oil-shales", and natural gas and petroleum occurring in the accompanying sandstones as developed in the Stony Creek oil fields, two general views have been held. On the one hand, it has been thought that the various hydro-carbons are of secondary origin, derived from sources outside of the Albert series. The second view is that the hydro-carbons are indigenous to the shales and that they have been derived from organic matter entombed in the sediments. This latter view of the origin of the hydro-carbons seems particularly applicable to the known facts in connexion with the Albert series.

BIBLIOGRAPHY.

1. Bailey, L. W., and Ells, R. W., Geol. Sur. Can., Report of Progress, 1876–77.

2. Dawson, W. J.....Acadian Geology.

3. Ells, R. W.........Dept. of Mines, Bituminous or Oil-Shales of New Brunswick and Nova Scotia, 1910.

4. Ells, S. C..........Geol. Surv. Can., Map 35A, 1911.

5. Kramm, H. E.....Geol. Surv. Can., Summary Report for 1911.

6. Lambe, L. M......Geol. Surv. Can., Memoir No. 3, 1910.

7. Young, G. A......Geol. Surv. Can., Summary Report for 1911.

ANNOTATED GUIDE.

MONCTON TO ST. JOHN.

(G. A. Young.)

Miles and Kilometres.

0 m. 0 km. **Moncton**—Alt. 50 ft. (15·2 m.). The Intercolonial railway leaving Moncton, runs in a southwesterly direction up the valley of Petitcodiac river, crosses a low summit with an altitude of 167 feet (50·9 m.) and enters the valley of Kennebecasis river which flows in a southwest direction. The railway follows the valley of Kennebecasis river to the head of Kennebecasis bay, a long lake-expansion of St. John river. The railway, at this point leaves the waterway; farther on it again skirts the shore of the lake, and finally leaving it for a space of about 6 miles (9·6 km.) runs directly to St. John city, situated on the Bay of Fundy coast, at the mouth of St. John river.

Throughout the greater part of the distance from Moncton to St. John, the railway runs parallel with and from 5 to 10 miles (8 to 16 km.) north of the foot of Caledonia mountain. This upland area with a mean altitude of about 1,000 feet (300 m.) is composed chiefly of Pre-Cambrian rocks of igneous and sedimentary origin. This area of ancient strata extends along the coast to St. John city and beyond, but towards St. John and to the southwest, the country underlain by these rocks is much lower than is the case to the northeast. The Pre-Cambrian area as far southwest as St. John, is bordered on the northwest by Carboniferous measures and immediately along the border these belong to pre-Millstone Grit divisions. These Carboniferous measures for many miles southwest of Moncton, extend to the north and west to join the main Carboniferous area of New Brunswick. Farther to the southwest, however, the Carboniferous strata are confined to a long band-like area bounded on both sides by ridges of Pre-Cambrian beds.

89·2 m. 143·5 km. **St. John.**

ST. JOHN AND VICINITY.*

(G. A. Young.)

INTRODUCTION.

The neighbourhood of St. John city is of special geological interest since it includes a portion of the Cambrian basin which has furnished so much palæontological material to Doctor G. F. Matthew. In the immediate neighborhood also, occur the 'Fern Ledges' from which many plant remains have been recovered whose age has been variously assigned to the Silurian, Devonian, and Carboniferous.

In the neighborhood of St. John, the following formations and groups are developed.

Carboniferous..	Red Head formation.†	
	Mispeck formation	
	Little River group	Cordaite formation. Dadoxylon formation.
	Bloomsbury formation	
Cambrian and Ordovician..	St. John group.	
Pre-Cambrian..	Crystalline limestone, quartzite, schists, gneiss, granite, etc.	

The various groups of strata are exposed over elongated areas all trending northeastward parallel with the coast of the Bay of Fundy and with the axial lines of the more prominent physical features. The Pre-Cambrian rocks are developed over a wide zone stretching for more than 100 miles (160 km.) along or near the Bay of Fundy coast. The Cambrian measures are confined in the main, to an area almost completely encircled by the Pre-Cambrian strata and reaching for 30 miles (48 km.) northeastward from St. John city. Minor parallel basins of Cambrian beds lie to the northeast within the same general Pre-Cambrian region. The Little River group together with the immediately underlying and overlying formations, outcrops over an elongated area situated southeast of the St. John Cambrian basin.

* See Map,—St. John and Vicinity.

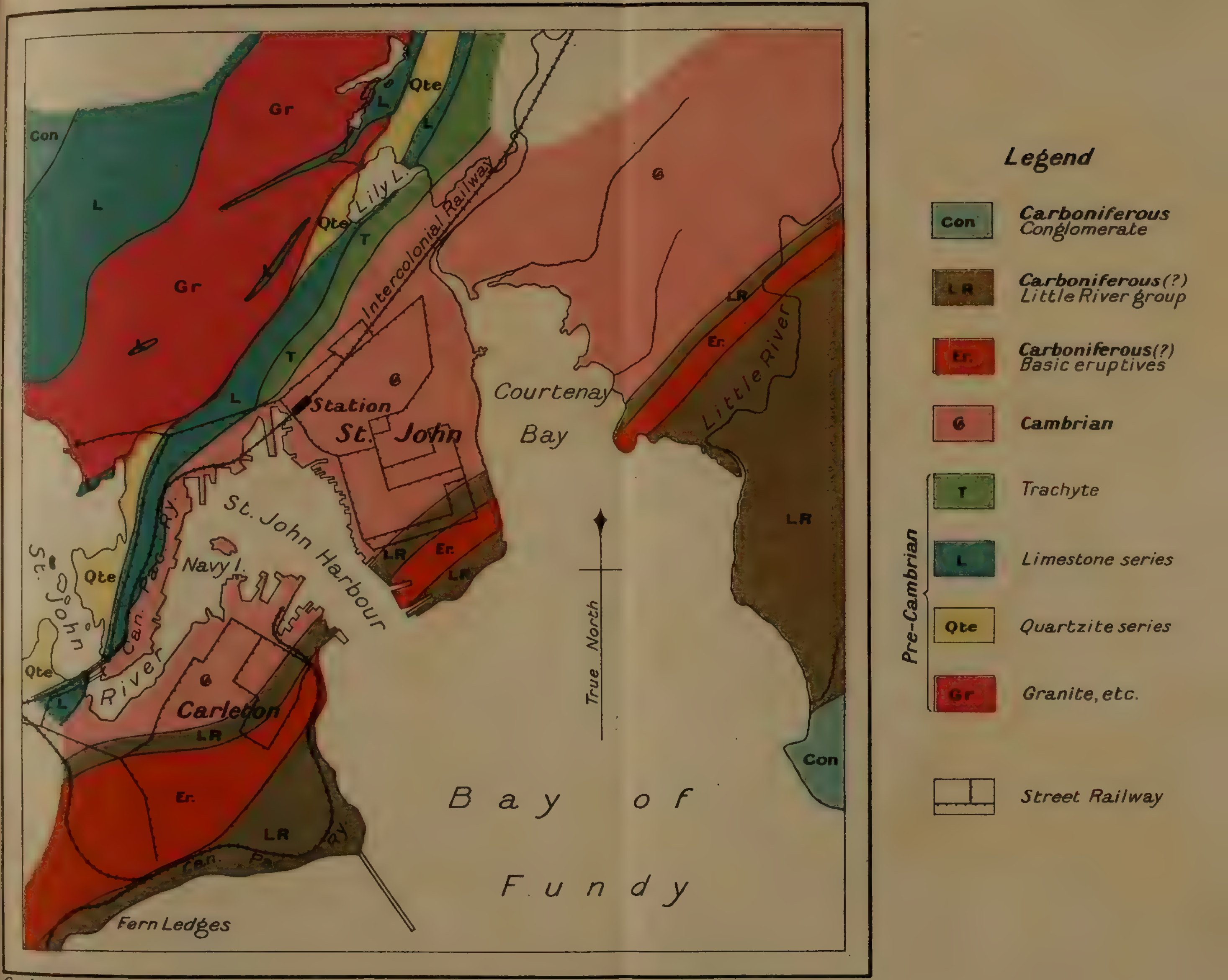
† The term, Red Head formation, is applied provisionally to certain strata at one time classed as Lower Carboniferous Conglomerate.

The details of the geological structures of the region are largely unknown. The Pre-Cambrian strata are presumably much faulted and folded. They have been intruded by large and small bodies of plutonic rocks. Different broad divisions of the Pre-Cambrian are developed along northeasterly trending axial lines and this mode of distribution doubtless indicates that the axes of folding and the strikes of the major faults are also parallel with the same general direction. The Cambrian and Carboniferous measures are also folded along northeasterly trending axes, but, whereas the Cambrian beds in places are tightly folded and overturned, the Carboniferous measures lie in open folds.

The *Pre-Cambrian* strata include both sedimentary and volcanic types probably belonging to groups of greatly differing ages. So far as we know, all have been intruded by plutonic masses varying in composition from gabbro to granite and not all of the same age. Possibly some of the plutonic rocks classed with the Pre-Cambrian may be of Palæozoic age and the same may be true of some of the volcanic rocks and even of some of the metamorphosed sediments. The Pre-Cambrian rocks have been divided into various divisions grouped under the terms Laurentian and Huronian. The Laurentian has been described as characteristically composed of crystalline limestone, quartzite, various schists, gneisses and granitic rocks. The Huronian has been defined as composed of great thicknesses of volcanic rocks including flows and pyroclastic types. The correlation of the volcanic strata with the Huronian as now defined, cannot be upheld. The correlation of the crystalline limestones and associated strata with the Laurentian is also of doubtful value.

The Pre-Cambrian rocks were greatly deformed, intruded by plutonic bodies and deeply eroded certainly earlier than Middle Cambrian time and in all probability earlier than Lower Cambrian time.

The *Cambrian* and *Ordovician* strata have been divided by Dr. Matthew into a number of divisions. These are presented in the following table based on one prepared by Matthew.



Geological Survey, Canada

St. John and Vicinity

Miles 0 1 2
Kilometres 0 1 2 3

		Thickness.	
		Feet.	Metres.
Lower Ordovician.	Bretonian.	700	213
Cambrian.	Johannian.	750	228
	Acadian.	200	61
Basal Cambrian.	Etcheminian.	1,200	365
	Coldbrookian.	?	?

The Acadian, Johannian and Bretonian together compose the St. John group which consists largely of dark slates and very fine sandstones. Fossiliferous beds occur at many horizons.

The Etcheminian strata are shales, sandstones and conglomerates and fossils are not common in them. The Coldbrookian consists of various types of volcanic rocks.

Dr. Matthew regards the St. John group as being the equivalent of the whole of the Cambrian proper including the Lower Cambrian, Olenellus zone or its equivalent, and a part of the lower Ordovician. The Etcheminian, because in certain places it seems stratigraphically unconformable to the overlying Acadian and because it varies widely in thickness from place to place, is thought by Dr. Matthew to unconformably underlie the Cambrian proper. The Etcheminian is stated to contain a fauna of Cambrian aspect but of an earlier type than that customarily classed in other regions with the Olenellus zone. The Coldbrookian is described by the same author as formed of

volcanic flows and ejectementa older than the Etcheminian but still of Palæozoic age.

Dr. C. D. Walcott has presented arguments to show that the lowest division of the St. John group, the Acadian, is of Middle Cambrian age and belongs to the horizon of the Paradoxides fauna. By the same authority the Etcheminian is regarded as a phase of the Lower Cambrian. The variations in thickness of the Etcheminian from place to place are believed to be due to the presence of inequalities in the original floor of the Cambrian basin whereby in some places a thousand feet of Etcheminian strata were deposited, in others only a hundred feet or less, while in others the Middle Cambrian rests directly on the Pre-Cambrian. Evidence is given to show that the unconformities which in some places appear to exist between the Acadian and Etcheminian are, in some instances at least, due to faulting and minor movements attendant on the deformation of the Cambrian basin as a whole. The Coldbrookian is classed with the Pre-Cambrain as had been done by earlier writers.

The fine muds and sands of the St. John group and the coarser detrital material of the basal formation, the Etcheminian, were laid down in a sea having a very uneven bottom and which apparently existed continuously throughout the greater part of Cambrian time and on into the opening epochs of Ordovician time. It is assumed that this sea withdrew temporarily at least, during the Ordovician period. Elsewhere in the Maritime Provinces, marine Silurian, Devonian and Carboniferous measures are extensively developed but these if ever present in the immediate vicinity of St. John, were removed by erosion before mid-Carboniferous time and the Cambrian beds were faulted and closely folded along axial lines pursuing a general northeasterly course.

The *Bloomsbury*, *Dadoxylon* and *Cordaite* formations as developed in the neighborhood of St. John, succeed the Cambrian measures on the south and in places at least, are brought against them by faulting. The Dadoxylon and Cordaite formations together compose the Little River group (*)

On the eastern shores of Courtenay bay, these measures, including a band of igneous rocks, are developed on the

(*) On the map of St. John and vicinity, t e Bloomsbury division has been included under the term, Little River group.

northern limb of an open synclinal fold. The strata dip in a southeasterly direction at angles ranging from 65° in the north to 20 ° in the south towards the centre of the syncline. The beds are exposed at intervals only. Their thickness is approximately 4,000 feet (1,220 m.). In the lower portion of the series, at the faulted contact with the Cambrian, the beds for a few hundred feet in thickness are largely reddish conglomerates and sandstones with beds of greenish shale; these measures compose the Bloomsbury formation. They are succeeded by greyish and greenish sandstones and shales forming the Dadoxylon formation. Above them lie dark green shales and arenaceous shales with fewer sandy measures: these belong to the Cordaite formation. Towards the base of this general series, occurs a band of igneous rocks, largely diabase. These igneous rocks are probably, for the most part, contemporaneous extrusives though there is some evidence that they are in part at least, intrusives.

The lower divisions, including the igneous member, of the above general assemblage, occur also in the southern part of St. John city and along the shore to the west on the western side of St. John harbour. In the western extension at a locality known as the Fern Ledges and a short distance farther west at Duck Cove, the sedimentary beds have yielded to collectors a large number of plant species. First systematically described by J. W. Dawson, the plants were then considered to be Devonian. In more recent years, Dr. Matthew has contended that the containing beds are of Silurian age, while amongst others, Dr. White and Dr. Kidston have stated that the plants are of mid-Carboniferous, Pennsylvanian age. The stratigraphical evidence regarding the age of the Little River group is discussed in the immediately succeeding paragraphs.

The *Mispeck* formation consists largely of red conglomerates, sandstones and shales. They overlie the measures of the Little River group on the northern limb of the synclinal on Courtenay bay [**1**], and are repeated in a similar position on the southern limb of the same fold. The Mispeck beds in the Courtenay Bay district, appear to conformably succeed the strata of the Little River group but Dr. Matthew believes that the Mispeck is unconformable to the Little River group. This belief is founded on the phenomena exhibited at a locality a few miles to the

southwest of St. John where the Mispeck beds rest directly on Pre-Cambrian strata. In reference to this locality, Dr. Matthew states that since the Mispeck conglomerate there "contains rolled fragments of Silurian corals, the whole series below it to the horizon of these corals must have been denuded before or during its (the Mispeck) formation." The relations thus described may however, be explained as due to overlap and not as indicating the existence of an unconformity between the Mispeck and Little River group.*

The existence or non-existence of an unconformity between the Little River group and overlying Mispeck is an important point in the discussion of the age of the Little River measures to which belong the strata of the Fern Ledges. If an unconformity exists, it forms a link in the chain of stratigraphical evidence tending to place the horizon of the Little River group below the Carboniferous.

The *Red Head* formation† consists chiefly of coarse, red conglomerate and sandstone. These measures occur over a considerable area situated towards the centre of the synclinal basin of Little river and Mispeck strata exposed along the shore of Courtenay bay. The measures of the Red Head formation are not exposed in actual contact with the Mispeck beds. The relative areal distribution of the two series of strata, the marked difference in the direction of dip of the two formations, and the presence in the Red Head conglomerates of pebbles of sandstone and shale closely resembling rocks of the Mispeck formation, are all factors indicating that the Red Head beds are unconformably above the Mispeck measures. The physical characters of the strata of the Red Head formation also indicate that these measures are younger than the neighbouring beds of the Little River and Mispeck formations. The conglomerates and sandstones of the Red Head formation are only loosely cemented whereas the Mispeck and Little River beds, especially those of the latter formation, are more compact and in places at least, have suffered a slight amount of shearing not found to have affected the Red Head beds. It is remotely possible, however, that the Red Head formation does not overlie the Mispeck for along the eastern side of the area of Red Head beds,

*On the map of St. John and vicinity, the southern part of area represented as being occupied by Little River group is doubtless underlain by Mispeck strata.

†On the map of St. John and vicinity, the areas occupied by the Red Head formation are mapped as 'Carboniferous Conglomerate.'

are exposures of schists and gneissic rocks apparently altogether foreign in character to the strata of the Little River and Mispeck formations. It has been suggested that these schists and gneisses which occur towards the centre of the syncline of Mispeck and Little River strata, are deformed contemporaneous volcanic rocks. Possibly, however, they are of much greater age and it may be that the Red Head beds rest directly on them and not on the Mispeck formation

The red strata of the Red Head formation outcrop over a second considerable area lying northwest of St. John city. At this locality, the measures repose on Pre-Cambrian strata. They extend to the shores of Kennebecasis lake and lithologically similar strata outcrop on Kennebecasis island where they are conformably succeeded by a series of grey sandstones and shales with plant-bearing beds. The late Dr. Ells stated that the lower red strata on Kennebecasis island, the supposed equivalents of the Red Head formation, have been traced westward to the Maine boundary and there found to be the equivalents of the Perry formation. The Perry on the evidence of its contained plants has been assigned by Dr. David White to the Devonian. Both Dr. Ells and Dr. Matthew correlate the upper, grey plant-bearing beds of Kennebecasis island with the Albert series of New Brunswick and the Horton series of Nova Scotia. By Sir. J. W. Dawson, L. M. Lambe, and other paleontologists, the Albert and Horton series are considered to be of Lower Carboniferous age and older than the Windsor marine limestone.

Paleobotanical material has been collected by Mr. W. J. Wilson from the plant-bearing beds of the upper grey series on Kennebecasis island. The flora indicates that the containing measures are of early Carboniferous age and that, at least approximately, they are the equivalents of the Albert and Horton series

The measures occuring on Kennebecasis island, as the above evidence indicates, are of Lower Carboniferous age or possibly in part of upper Devonian age. If the red strata of Kennebecasis island are the equivalents of the Red Head formation which apparently unconformably overlies the Mispeck and which in turn overlies the Little River group, then it is manifest that the Little River group and the contained Fern Ledges, cannot be younger

than Devonian and that as far as the stratigraphical evidence indicates, may be even Silurian as contended by Dr. Matthew.

The plant-bearing Fern Ledges undoubtedly belong to the Little River group and according to various eminent authorities, the plants indicate in the strongest fashion possible that the strata are of mid-Carboniferous age. If this conclusion is correct then it must be conceded that either the Red Head beds are not younger than the Little River group, or if they are younger, that they are much younger than the lithologically similar strata occurring on Kennebecasis island.

CAMBRIAN AND PRE-CAMBRIAN SECTION, ST. JOHN CITY.*

The Cambrian strata underlying St. John city are arranged in three synclinal folds whose axes strike approximately northeast. The folds, in general, are overturned and the strata are usually either vertical or dip steeply towards the south. The basin is traversed by a few major faults striking parallel with the course of the axes of folding.

The centre of the northern of the three synclines is indicated by a depression known as the "Valley" and in which lies the yard of the Intercolonial railway. The centre of the syncline is occupied by strata belonging to the Bretonian but the measures are largely concealed beneath the drift-covered floor of the Valley. The axis of the syncline passes on the south side of the depression, at the foot of a steep hill. On the opposite northern slope of the Valley are outcrops of Acadian, Johannian and Etcheminian strata forming the north limb of the syncline. Pre-Cambrian strata are exposed on the summit of the hill.

On Meadow street, just south of the junction of this street and City road, at the foot of the slope forming the southwest side of the Valley, a rock-cutting exposes strata belonging to the Bretonian, the highest of the Cambrian divisions. The measures are dark slates with many thin beds of hard, fine sandstone. At the beginning of the

* See Map,—Part of St. John City.

Geological Survey, Canada.

Part of St. John City

Feet
500 0 1000 2000

Metres
100 0 200 400 600

(Scale of map is approximate)

rock-cutting, the strata dip southerly at angles of about 45°. A few yards farther, they are twisted and torn, while just beyond this point, they again dip regularly at high angles to the south. The general attitude of the beds in the rock cutting suggests the presence of a synclinal axis and this may be the main synclinal axis of the northern syncline.

Fossils have not been found in these measures but in the corresponding strata in the next syncline to the south there have been found various characteristic Upper Cambrian forms including, *Peltura scarabeoides* and other trilobites of the genera Agnostus and Ctenopyge.

Along the south side of City road, are outcrops of the dark slates and fine sandstones of the Bretonian, striking almost parallel with the street and presumably situated on the northern limb of the synclinal fold and not far removed from the axial line. If this be so, the strata underlying the Valley and outcropping on the northern slopes of the Valley are arranged in descending order.

No strata outcrop along Stanley street which crosses the Valley at right angles to its course. Small outcrops of dark greenish or greyish slates with fine sandstone beds occur in rock cuttings along the railway tracks beneath the bridge on Stanley street and to the east and west of this bridge. These measures dip steeply to the south and strike at a very acute angle across the course of the railway. The concealed contact between these lighter coloured strata and the darker coloured shales of the Bretonian division probably crosses Stanley street not far north of the junction of this street and City road. The lighter coloured measures underlie the dark Bretonian slates and presumably belong to the Johannian division.

Though no strata outcrop on Stanley street north of the railway, there are a number of exposures of slate and sandstone along the streets and lanes immediately to the east. The measures there exposed belong in part to the concealed horizons that belong, stratigraphically, between the beds in the railway cuttings and the measures exposed on Wright street at the junction with Gooderich street. On Gooderich street and at the head of this street, a series of exposures forms a nearly continuous section of the Cambrian down to the contact with the Pre-Cambrian.

At the junction of Wright and Gooderich streets are exposures of dark greenish slates and many beds of fine sandstone. The strata dip southwards at angles of 70° to 80°. These measures belong to the Johannian division. Northward along Gooderich street, a progressive change takes place in the strata, the sandstone beds are thinner and fewer and the slates darker in colour. Towards the head of the street, the strata are mainly dark slates with thin, disrupted beds of fine sandstone. These measures belong to the Acadian division.

At the northwest corner of the junction of Seely and Wright streets are exposed remnants of fossiliferous shale, though this is not now a good collecting place. The common fossils still to be obtained are; *Paradoxides eteminicus*, *Ctenocephalus matthewi*, *Liostracus tener Linnarssonia transversa*, and *Acrothele matthewi*. Some years ago, members of the Protolenus fauna, including *Protolenus paradoxides*, were found by Mr. J. E. Narraway between the above fossiliferous layer and the white sandstone at the back of the quarry, but this outcrop is no longer available. The strata belong to the Acadian division and by Dr. Matthew are regarded as the equivalent of the Lower Cambrian of other regions. By Dr. Walcott and others, the fauna is held to be of Middle Cambrian age.

In the low rocky mound and small quarry at the head of Gooderich street, there are exposed to the north of, and therefore below the fossiliferous shales, about 70 feet (21 m.) of nearly vertical shales and sandstones. These are succeeded by a 20-foot bed of white, comparatively coarse sandstone. Beyond this distinctive sandstone bed are exposures of dark grey and purplish sandstones and shales with one thin bed of white sandstone separated from the main bed by about one foot of the dark rocks. A thickness of about 50 feet (15 m.) of the dark sandstones and shales is exposed. To the north, after a concealed interval of about 60 feet (18 m.), rises a low ridge of dense, green trachyte belonging to the Pre-Cambrian. The strata in general strike to the southwest and dip at very high angles to the southeast. In spite of local slips and warpings in the beds, the whole series appears conformable.

The massive bed of white sandstone marks the base of the Acadian. The dark grey and purple sandstones

Etcheminian at right, basal quartzite of Cambrian (centre) and Protolenus bed (left). Seely street, St. John, N.B.

Base of Etcheminian unconformably on the Pre-Cambrian, Park street, St. John, N.B

and shales represent the Etcheminian. The green trachyte belongs to the Coldbrookian.

The white sandstone is a constant feature at the same horizon over a great part of the whole Cambrian basin. By Dr. Matthew this bed is regarded as the base of the Lower Cambrian while by Dr. Walcott it is held to mark the base of the Middle Cambrian as the fauna of the immediately overlying beds indicates. Under this view the Etcheminian is of Lower Cambrian age. By Dr. Matthew the trachyte is considered to be an effusive flow closely associated as regards age with the overlying Etcheminian both of which formations are thought to be older than the Lower Cambrian or Olenellus zone.

Seely street follows a nearly due east course from the head of Gooderich street, almost parallel with the strike of the Cambrian (Acadian) measures. At the junction of Seely and Prospect streets, the strata are well exposed. The measures consist of dark slates alternating with harder beds usually less than one inch in thickness.

On the eastern side of the road leading north from the eastern end of Seely street, are exposures of nearly vertical, dark slates with thin beds of dark, fine grained sandstone. To the north of these beds, the white sandstone, the base of the Middle Cambrian, is exposed in a small ridge. The width of the outcrop along the roadside is about 40 feet (12 m.). Immediately overlying the white sandstone is a dark, coarse sandstone, while underlying it are dark greenish sandstones belonging to the Lower (?) Cambrian, Etcheminian division. The strata dip to the south-east at an angle of about 60°. The contact of the Etcheminian with the underlying volcanics of the Coldbrookian is not exposed along the roadside. The first exposures of the underlying volcanics is a few yards north of a branch road leading to the northeast.

The basal beds of the Cambrian are only imperfectly exposed along the roadside. The following section as measured by Dr. Walcott in the immediate neighborhood, indicates the general character of the strata. The measures are tabulated in descending order, that is, in the order in which they are exposed along the road from south to north.

Middle Cambrian;—

b. Greenish and dark shales and fine sandstones........

a. Light grey, quartzitic sandstone 40-45 feet (12-14 m.)

Lower (?) Cambrian (Etcheminian);—

c. Reddish-purple and greenish shales and thin sandstones................52 feet (15·8 m.)

b. Concealed (presumably shales and sandstones).......................85 feet (26 m.)

a. Dark reddish conglomerates, sandstone and shale...................12 feet (3·6 m.)

Pre-Cambrian.—

The lowermost beds of the Etcheminian and the nature of the contact with the Coldbrookian (Pre-Cambrian) is indicated in a series of exposures along the branch road leading to the northeast. This road passes along the south side of a low rocky ridge of the dark green, fine-grained trachyte immediately underlying the Cambrian beds. The Pre-Cambrian volcanic rock in some of the exposures on the road side is reddish in colour and in places possesses an irregular, shale-like parting, apparently resulting from weathering. At some points, the igneous rock is less altered and is of a pale greenish colour. At several places are small exposures of fine greyish or slightly reddish conglomerate overlying decomposed trachyte and evidently mainly composed of detritus from the Pre-Cambrian volcanic.

The purple weathering, green volcanic rocks underlying the Cambrian forms a band striking to the northeast. This band where it is traversed by a path running northward to Mount Pleasant avenue is about 700 feet (215 m.) wide. Along the pathway outcrops are few but the rocks are well exposed on the ridges rising on both sides. The igneous rock in most places is quite uniform in appearance being a fine grained, almost dense trachyte with minute feldspar phenocrysts. In some places as along Mount Pleasant avenue where it skirts the shores of Lily lake, the rock has a fragmental structure and appears to be of tuffaceous origin. The occurrence of this fragmental variety suggests that the igneous rock as a whole is of effusive origin. The age of the rock is supposedly Pre-Cambrian since it

underlies and has furnished detrital material to the Cambrian beds and since nowhere in the general Cambrian basin have volcanic rocks been described as occurring interstratified with Cambrian measures.

The relations of the trachyte to the other Pre-Cambrian strata exposed over a very wide area to the north, is unknown. On the north side of the volcanic rock lies a band of crystalline limestone and the two rocks are in contact for a distance of at least two miles. The constancy of this feature considered in connexion with the nature of the volcanic rock, may be taken to indicate that the trachyte is of the same age as the limestone strata. No decisive evidence is available to indicate whether the igneous rock is stratigraphically above or below the limestone.

The band of crystalline limestone extends in a southwest-northeast direction for at least 4 miles (6·4 km.). At the end of the path traversing the band of trachyte, the contact between the volcanic and the crystalline limestone follows southwesterly along Mount Pleasant avenue. On the north side of this road are many exposures of white crystalline limestone traversed by broken and bent dykes or sills of diabase. To the northeast, the full width of the band of limestone is exposed on the eastern shores of Lily lake. In this neighborhood, the width of the crytalline limestone band is about 250 feet (76 m.). To the southwest, the band rapidly expands to a maximum width of about 950 feet (290 m.).

The character of the limestone measures is exhibited in a series of exposures along the road known as Lake Drive North which leads from Mount Pleasant avenue past the west end of Lily lake and along the shores of a group of smaller lakes to the north. Where this road crosses the band of crytalline limestone, the rocks at one point are flexed into a syncline and other indications of the deformation of the strata are present. The original bedding planes are indicated by variations in texture, colour, etc. The northern margin of the limestone band is marked by a zone of black rocks, partly slates, partly diabase.

Just beyond the first cross road on Lake Drive North, are exposures of dense, light coloured quartzite belonging to a band of such rocks having a width of about 800 feet (245 m.). This band of rocks forms the northwestern boundary of the limestone series for some distance both to the northeast and southwest, except where the quartzites

have been replaced by intrusive rocks. The quartzite and limestone presumably belong to the same series but it is not known whether the quartzite underlies or overlies the limestone.

The quartzites are exposed at intervals along Lake Drive North. At a series of exposures where this roadway rises over a low hill, the quartzites are comparatively coarse grained and are distinctly bedded, the strata being nearly vertical. The quartzites are exposed along the roadsides to the top of the rise but farther on, as the road descends to where a branch road runs east to the shores of Lily lake, decomposed gneissic rocks outcrop.

Gneissic rocks are exposed along the driveway from the point of junction of the branch road, northward to where the main road bends to the northeast beside a small stream. The gneisses are of medium to fine grain, are dark coloured, flecked and streaked with pink and are strikingly foliated. The rocks have the mineral composition of a biotite or hornblende granite and appear to be deformed granites. They occupy a narrow band-like area reaching a few hundred yards to the east but extending much farther to the west where they join a large area of granite. The relations of the gneissic rocks with the granite are unknown. Possibly the gneissic rocks have resulted from the local deformation of the granite.

The area of deformed granite is bounded on the north by a band of crytalline limestone which extends to the southwest as a long narrow band surrounded by granite. The limestone is bounded on the northwest side by granite and the roadway crosses and recrosses the line of contact. The limestone is of the same general character as the rock of the calcareous band striking across Lily lake. The granite occurring on the northwest side of the limestone band, is of medium grain, usually pink in colour and poor in coloured bisilicates which include both biotite and hornblende. In the neighborhood of the contact with the limestone, aplite dykes occur in the calcareous rocks.

The granite body shows slight variations in texture and composition from place to place. Small patches of foreign material occur. Small detached blocks of crystalline limestone also lie within the granitic rocks; one such block with a major diameter of about 35 feet occurs on the roadside towards the western end of the larger of the three lakes lying north of Lily lake. Along the road leading

northward from the end of the same lake, exposures of granite alternate with others of diorite, diabase, quartzite and various types of schists. Some of the diabase rocks cut the granite, but the diorite and various types of schists are probably all older than the granite.

SUSPENSION BRIDGE.*

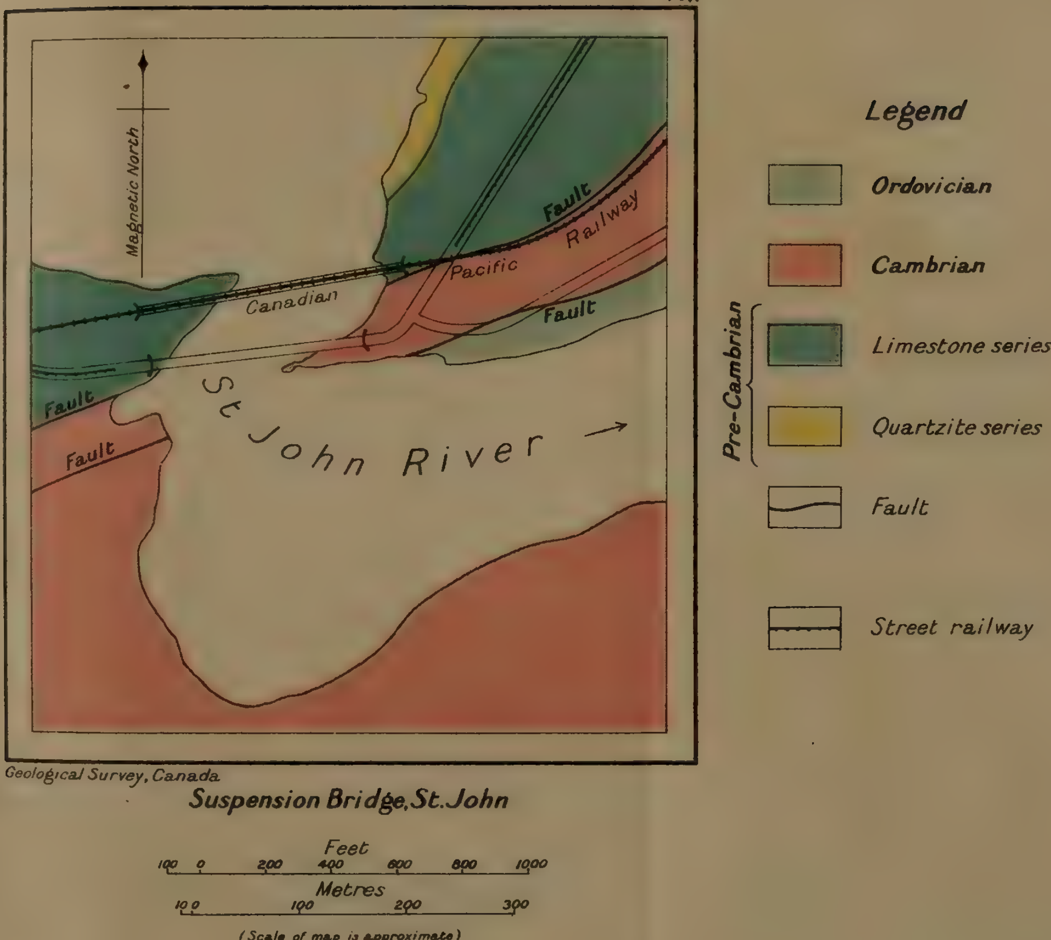
General Description.—At the locality known as Suspension bridge, the St. John river is spanned by two bridges—a railway bridge and a highway bridge. At this point the river is confined for about 300 feet (90 m.) to a gorge-like channel about 300 feet (90 m.) wide through which the waters rush in a southerly direction. Below this point the river channel suddenly widens, abruptly turns to the northeast, and follows this course for about one mile, to the head of St. John harbour. Above the constricted channel at the bridges, the river widens and about 500 yards (460 m.) farther up, again contracts. Above the second constriction, known as the "upper falls", the river widens to lake-like dimensions and after abruptly bending to the northwest continues with this character for many miles. A long arm of this lake extends to the northeast and this arm together with the northwesterly extending lake-like expansion of the St. John river is known as Kennebecasis lake.

The lake bottom is very irregular, with deep channels in which the water reaches depths of between 100 feet and 200 feet (30 m. to 60 m.). At the constriction known as the upper falls, the water is only about 25 feet (7·5 m.) deep. Below this point the channel is deep; even in the gorge-like portion at Suspension bridge, the water is 100 feet (30 m.) deep but at the exit from the short gorge at the lower falls, the water shoals to a depth of about 25 feet (7·5 m.). In the channel-way below Suspension bridge as far as Navy island at the head of St. John Harbour, the depth of the water varies between 30 feet and 100 feet (9 m. and 30 m.).

The waters of Kennebecasis lake, though in direct communication with the sea, always stand above mean tide level. In the spring of the year, the waters of the lake lie at a height of 9 feet (2·75 m.) or more above mean tide; later in the year as the volume of fresh water draining

*See Map—Suspension Bridge.

A1.



Suspension Bridge, St. John

into the lake decreases, the level of the lake falls to about 3 feet (1 m.) above mean tide. The cause of the higher level of the lake waters relative to mean sea level is due to the constricted nature of the outlet of the lake and to the fact that besides the great volume of sea water entering the lake twice each day there is also an additional large amount of fresh water to be discharged.

The level of high tide in St. John harbour varies between 10 feet and 14 feet (3 m. and 4·2 m.) above mean tide. The waters of the lake rise with the tide only 15 or 18 inches (0·38 or 0·46 m.), therefore at high tide during the latter part of the summer, the water in the St. John channel at Suspension bridge stands 6 to 10 feet (1·8 to 3 m.) above the level of the lake and as a result of the contracted and shallow nature of the channel at the upper falls, the waters there fall inwards. During other portions of the day when the tide level sinks below the lake level, the falls are reversed in direction and the waters fall outwards.

The general configuration of the constricted channel at Suspension bridge is sufficient evidence to indicate that it is not of normal origin. Kennebecasis lake presents many of the general characters of a dammed body of water. The lake and the contiguous lake-like expansions of the St. John river occupy a series of depressions that are portions of valleys belonging to two systems, one of which follows a northwest-southeast course, and the other a northeast-southwest course. The channel of the St. John below Suspension bridge follows a northeast course and therefore belongs to one of the above systems. The lower channel of the river is apparently continued by the depression traversing St. John city and known as the Valley. At Suspension bridge, the depression occupied by the mouth of the river abruptly ends, being cut off by a high ridge from a valley extending some miles to the southwest. It is not improbable that the dividing ridge is composed of unconsolidated material of Glacial and post-Glacial age and that at one time the valleys now heading in this ridge were continuous.

The lake of the lower St. John, whose bottom in places lies nearly 200 feet (60 m.) below sea level, has probably been formed by the empounding of the waters of the drainage system by dams choking the old outlet or outlets. These dams are presumably of Glacial or post-Glacial age. Forced to seek a new outlet, the waters for a time

may have reached the sea by a number of channels, but eventually they appear to have broken over and then through the comparatively low rocky ridge at Suspension bridge and to have found their way to the sea by means of the old valley entered at this place.

The rocks forming the walls of the canyon-like outlet of the St. John river at Suspension bridge are of Pre-Cambrian, Cambrian and Ordovician age. The strata of these three groups are separated from one another by faults that strike in a northeasterly direction. The strata are, in general, steeply inclined and strike in an easterly direction.

The Pre-Cambrian measures outcrop on both sides of the constricted passageway of the St. John and form the northern portion of the walls. They are bounded on the south by Cambrian beds from which they are separated by a fault. The Pre-Cambrian at this place is represented by a band of quartzite flanked on the south by a band of crystalline limestone with beds of black slates and sills or dykes of diabase. The strata are folded, faulted and torn, but in general stand with nearly vertical attitudes.

The Cambrian rocks are largely dark slates and fine sandstone. On the eastern banks of the gorge they form a narrow band separated by a fault from the Pre-Cambrian on the north and by another fault from the Ordovician on the south. These beds have been assigned to the Johannian by Dr. Matthew. The measures bounded by the same faults, occur on the western side of the narrows of the river. They are bounded on the north by Pre-Cambrian rocks while on the south side lie conglomerate, sandstone and shale beds probably of another horizon of the Cambrian, not the Johannian.

The Ordovician measures are largely dark shales. They are exposed in a narrow band along the northern shore of the river below Suspension bridge. The shales are not very fossiliferous, and contain only a few species which are common. *Tetragraptus quadribranchiatus* is the most common fossil, others being species of *Didymograptus*, *Clonograptus* and *Loganograptus*, beside the brachiopods, *Orthis electra major*, and *Strophomena atava*. The Ordovician beds are overturned since they dip southward at high angles thus appearing to underlie the Cambrian strata outcropping on the opposite, southern bank of the tidal river. The Ordovician measures are the highest

preserved members of an overturned syncline which includes the Dictyonema beds of Navy island situated about 1 mile (1·6 km.) to the northeast on the southern side of the channel. The thin-bedded, dark shales on Navy island, are, in places, extremely fossiliferous, *Dictyonema flabelliforme* being particularly abundant. Separated cranidia of trilobites are not uncommon, associated with the Dictyonemas, some of the species found here being *Parabolina heres grandis*, *Parabolinella posthuma*, *Leptoplastus latus*, and *Ctenopyge flagillifer*.

DETAILED DESCRIPTION.

At the end of the street car line on Douglas avenue, at the railway crossing, are exposures of Pre-Cambrian, white, crystalline limestone. The railway runs along the course of the fault separating the Pre-Cambrian from the Cambrian. In the rock cuttings along the north side of the railway, the Pre-Cambrian limestone is exposed, while on the south side of the railway steeply inclined, bent and twisted, dark slates and fine grained sandstones of Cambrian, (Johannian) age outcrop.

The position of the fault bounding the Cambrian on the south is indicated by certain exposures on the Strait Shore road which joins Douglas avenue about 200 feet (60 m.) beyond the railway crossing. On the Strait Shore road about 50 yards (45 m.) east of the junction with Douglas avenue, are outcrops of twisted and torn, Cambrian slates and sandstones. These measures are exposed on the north side of the road, while in the gutter on the same side of the road are exposures of dark shales supposedly of Ordovician age since they are lithologically very similar to the graptolite-bearing beds of this age outcropping a few yards to the south in the cliffs along the shore of the river. The fault plane separating the Cambrian and Ordovician, is visible in the cliff face at a point just opposite the anchor pier of the Suspension bridge.

From a view point on the western shore between the two bridges, the fault separating the Pre-Cambrian and Cambrian is plainly indicated in the steep rock cliffs about 20 feet (6 m.) south of the railway bridge. The position of the nearly vertical fault is made apparent by the contrast between the white, Pre-Cambrian limestone on the north

and the dark Cambrian slates on the south. The crystalline limestone beds as indicated by the associated dark rocks, are much torn. The limestones are succeeded on the north by quartzites and the boundary between these two formations is in part at least, a fault plane whose general course is indicated by the ledges of white quartzite outcropping beyond the railway bridge and a short distance

Fault between Tetragraptus shale and Acadian, near Suspension bridge, St, John, N.B.

back from and approximately parallel to the cliffs forming the shore of the river.

The fault plane separating the Cambrian and Ordovician is visible from the hillside south of the highway on the western side of the river. The two sets of strata do not sharply contrast in colour. The dense black, Ordovician shales form the cliff back to two ruined docks, while the greyer Cambrian measures form the rocky projection extending westward parallel with and to the south of the highway bridge.

The small, bay-like indentation on the west side of the river immediately below the highway bridge, marks the line of the fault between the Pre-Cambrian and Cambrian

on the west bank. The fault on the eastern shore between the Cambrian and Ordovician presumably continues on the west side of the river and apparently passes close to the small pavilion standing near the shore. The fault at this place brings lithologically dissimilar Cambrian beds into contact with one another.

SUSPENSION BRIDGE TO SEASIDE PARK (FERN LEDGES).

The street car route from Suspension bridge to Seaside park for a short distance follows a westerly course overlooking the St. John river which is bordered on both sides by Pre-Cambrian rocks consisting of crystalline limestone, quartzite, etc., and large intrusive bodies of granite and diorite. The street car route is situated on the northern slope of a ridge which possibly is composed altogether of unconsolidated materials since on the lower slopes, towards the river, heavy cuttings reveal a very considerable thickness of stratified clays and sands.

Shortly after leaving Suspension bridge, the street car route turns sharply to the southeast and passes along the western edge of the summit of the above mentioned hill. To the southwest extends a long broad valley joining the valley of the St. John to the southwest. This valley is continued on the eastern side of the ridge by the lower reaches of the St. John river and by the valley running northeasterly through St. John city.

At the junction with the street car line leading eastward to Carleton, are outcrops of dark, basic volcanic rocks. Similar rocks outcrop at intervals along and at the end of the street car route at Seaside park. These basic rocks form a thick zone apparently interbanded or interbedded with the lower portion of the Little River group. Similar rocks in a similar stratigraphical position outcrop in St. John city and farther east on the shore of Courtenay bay. The igneous rocks vary considerably in appearance from moderately coarse diabase to fine-grained, porphyritic and amygdaloidal varieties. In places they appear to have slightly metamorphosed the overlying sediments. The basic igneous rocks possibly are eruptives, though it is more probable that they form an intrusive, sill-like body.

At Seaside park, at the end of the street car line, the basic igneous rocks are exposed at intervals along the path leading across the railway to the shore and to the Fern Ledges. Where the path crosses the railway are exposures of quartzose sandstone belonging to the Dadoxylon division of the Little River group. The measures dip seaward (to the south) at an angle of 30°. Similar measures are exposed a short distance farther, but from this point to the beach, to the locality of the Fern Ledges, the strata are concealed.

FERN LEDGES.*

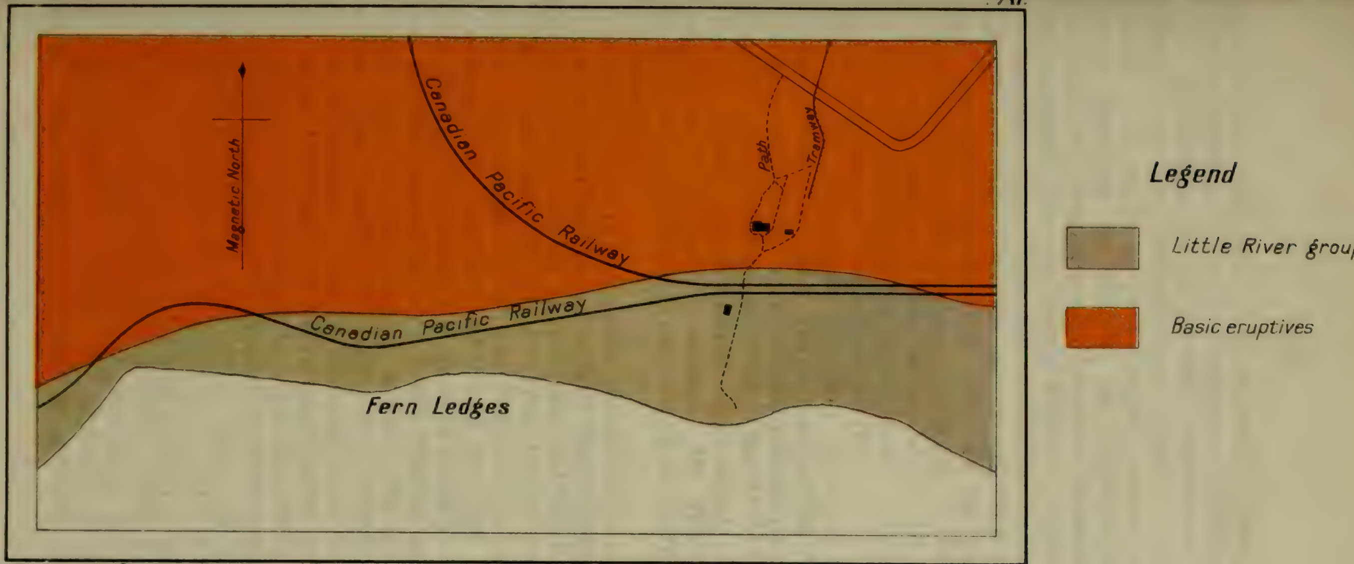
(Mary C. Stopes)

Editorial Note.—Recently Dr. Mary C. Stopes has prepared for the Geological Survey of Canada, a memoir on the flora of the Fern Ledges. This memoir is not yet published but permission has been obtained to make use of the information contained in the manuscript in the preparation of the following account of the geology and flora of the Fern Ledges. Dr. Stopes was able to assemble nearly all the original specimens of the Fern Ledges flora and studied them as well as a great mass of new material obtained from Duck Cove, a short distance west of the type locality. The following account is essentially an abstract of the unpublished memoir by Dr. Stopes. Certain portions of the manuscript have been extracted word for word; such portions are indicated by quotation marks.

"The fossil plants of the St. John Fern Ledges in the Little River group occupy a unique position in the annals of palæontology owing to the extensive........ discussions they have aroused ever since (so long ago as 1861) Sir W. Dawson began to describe them as representatives of a Devonian flora. Sir W. Dawson from time to time named and illustrated the majority of the species described from the beds. At this early date comparatively few figures of European and other American Palæozoic fossil plants were available for his use and so it is not surprising that Sir William made new species from most of the specimens. As a consequence, judging to-day by the list of species described from the locality, one receives the impression that the "Little River" flora is an isolated and peculiar one. In quite recent years, Dr. Matthew......has been publishing

* See Map—Fern Ledges.

A1.



Geological Survey, Canada

Fern Ledges

(Scale of map is approximate)

revisions and additions to this interesting flora and latterly he has maintained that the plants are of Silurian age."

Sir W. Dawson in his various descriptions of the flora pointed out the Carboniferous aspect of many of the species. "As early as 1866 Geinitz pointed out that the insects described by Scudder as Devonian were on the same slab as a fragment of *Pecopteris plumosa*" and that this suggested that the strata were of Carboniferous and not Devonian age. The controversy as to the age of the flora did not take a serious aspect until thirty years later when attention was forcibly directed to the matter in connexion with a discussion of the age of the Riversdale-Union formations of Nova Scotia which on floral, lithological and stratigraphical grounds were correlated with the Little River and associated strata.

Dr. J. F. Whiteaves in 1899, in a vice-presidental address to the American Association for the Advancement of Science presented extracts from manuscript reports prepared by Dr. Kidston and Dr. David White, in which both of these palæobotanists maintained that the Fern Ledges were of Carboniferous age. Dr. White in another publication very definitely correlated the Fern Ledges with the Pottsville.

In 1906, Dr. G. F. Matthew commenced a revision of the flora of the Fern Ledges and took up the position that the flora was Devonian, but later, in 1910, asserted that it was Silurian.

The classic locality for the Fern Ledges fossil plants is on the shore between high and low water, at Seaside park, a mile west of Carleton a suburb of St. John. "The same strata are repeated along the shore of Duck Cove, where the most prolific beds now lie, for the original sections at the Fern Ledges are both nearly worked out and have been covered to a considerable extent by the drifting sand and gravel of the shore. The same series also outcrops to the east of St. John harbour where some plants are to be found if they are carefully sought for, but the extent of alteration in the shales is much greater here, and the fossils are seldom sufficiently well preserved to repay collection, except merely for identification in the field." The same beds occur to the west of the Fern Ledges locality, and outcrop on the shore at Lepreau harbour where "fossil plants are to be found, but these specimens also have but little value beyond indicating the identity of the beds in which they occur. One may take it that practically all the plants

of importance to the palæobotanist originated from the Fern Ledge section of Carleton, or from one of the numerous beds a little further around the coast toward and just beyond Duck Cove."

"The Fern Ledges series consists of alternations of sandstones and shales. In the compact, heavy grey sandstones but few fossils, and those principally fragments of woody stumps, are to be found. In the numerous beds of fine grey or blackish shale, which is laminated and

The "Fern Ledges," St. John, N.B.

in many places, is considerably altered, a rich flora of debris occurs. The more or less altered shale occurs in beds ranging from a couple of inches to a couple of feet in thickness." At Duck Cove, at the present time the best collecting locality, the plant-containing bands are more numerous than in the original section at the Fern Ledges as reported by Hartt and Matthew. The beds dip at an angle of about 30° to 50°. There are several minor faults which tend to cause repetitions of the series but even allowing for this there cannot be less than 20 bands of plant-containing shales, of various thickness, most of them containing a great variety of plants.

Previous accounts seemed to indicate that the various shale bands might represent zones in a geological sense. This, however, does not appear to be the case though it is not impossible that extensive and careful work over the

whole outcrop may reveal definite assemblages in a definite sequence.

"The general appearance of the fine shale bands alternating with the sandstones, is that of a deltaic deposit, probably at the mouth of a great river or at its entry into a lake or it might be, the bend of a lagoon (the remarkable lack of marine fossils in the neighbourhood renders some such view very probable). The deposits appear to have collected rapidly (geologically speaking). The difference in the species of the plants brought down from time to time in the current of the river can be readily accounted for by slight changes in the course of the water, or by flood effects in different parts of its course. The Fern Ledges flora is the remains of the inland flora of the period, and one which had travelled down stream as debris for some distance before being entombed. It is, therefore, natural that sometimes one, and sometimes another species should preponderate in the various beds now appearing in consecutive order; but the sequence of these plant remains depended on local, fortuitous accidents, and do not appear to be an indication of appreciable differences of geological time."

The plants in this series of beds are found in two forms. (1) Scattered, isolated and infrequent trunks or branches, some of Calamites, but mostly of branches of gymnospermic wood of an ancient type generally known as Dadoxylon. These occur principally in the sandstones alternating with the shale bands. (2) The impressions of ferns, Cordaites, Calamites, and other plants, forming the debris of a rich, mixed flora, preserved in the series of shale bands. It is unfortunate that these impressions are all much altered. They often occur on slickensided surfaces, and locally the shales have quite a slaty cleavage. The plant impressions have been completely graphitized and most of them consist merely of a bright film or streak on the rock.

"Though over 80 "species" have been from time to time described from the Fern Ledges flora, among all these only about 40 are of value and have been determined on a sufficiently sound basis to make them of any real use in the comparison of this flora with others." In the following list are given only such species as are thought to have been determined from material that by competent palæobotanists would be universally considered to be

sufficiently good to enable the species to be reliably determined.

Calamites suckowi Brongnt.
Annularia sphenophylloides Zenker.
Annularia stellata Schlotheim sp.
Annularia latifoila Dawson sp.
Stigmaria ficoides
Adiantides obtusa Dawson sp.
Rhacopetris busseawa Steer
Sphenopteris marginata Dawson
Oligocarpia splendens Dawson sp.
Sphenopteris valida Dawson sp.
Pecopteris plumosa Artis.
Diplothmema subjurcatus Dawson sp.
Alethopteris lonchitica Schlotheim sp.
Megalopteris dawsoni Hartt sp.
Neuropteris heterophylla Brongnt.
Neuropteris gigantea Sternberg
Sporangites acuminata Dawson
Pteriopermostrabus bifurcatus Stopes
Dicranophyllum glabrum Dawson sp.
Whittleseya dawsoniana D. White
Whittleseya concinna Matthew
Cordaites rubbii Dawson
Cordaites principalis German sp.
Dadoxylon ouangondianum Dawson
Cordaianthus devonicus Dawson sp.
Cardiocarpon obliquum Dawson
Cardiocarpon baileyi Dawson
Cardiocarpon cornutum Dawson
Cardiocarpon crampii Hartt.

Every species of importance is a typical Carboniferous one. By David White the plant-bearing Fern Ledges have been correlated with the Pottsville; by Kidston they have been correlated with the European Lower Coal Measures. By White the upper part of the Pottsville is considered to be very nearly contemporaneous with the Lower Coal Measures of Europe. But it would appear that the Fern Ledges represent a somewhat higher zone than that assigned by White.

If a comparison be made between the Fern Ledges and Westphalian floras it is at once evident how remarkably

Westphalian is the character of the Fern Ledges flora. "The genus Megalopteris alone, is entirely unrepresented in the Westphalian of Europe, but it is a peculiar form which is confined (though recently Arker identified a small fragment from the British Coal Measures as belonging to this genus) to North America, where it has been recognized in beds of undoubtedly Pottsville age. Otherwise the leading species have not merely allies in the Westphalian flora of Europe, but are identical in the majority of cases. We may take it as indisputable that the Fern Ledges flora is of Westphalian age and that probably it corresponds in point of time most nearly to the lowest zone of the middle Westphalian. The specific identity between so many of the plants from Europe and Canada is a point of great interest in relation to the geographical distribution of the forms."

BIBLIOGRAPHY.

The general geology of the area in the vicinity of St. John city, and the faunas of the Cambrian and the flora of the Little River group have been exhaustively dealt with by Dr. G. F. Matthew in a long series of articles appearing in the Proceedings and Transactions of the Royal Society of Canada from volume I (1882-83) onwards. A few of the other more important contributions to the general subject are as follows:—

Bailey, L. W. Geol. Surv. Can., Report of Progress 1877-78.

Dawson, W. J. Acadian Geology.

Ells, R. W. Geol. Surv. Can., Geology and Mineral Resources of New Brunswick, 1907.

Walcott, C. D. Proceedings Washington Academy of Sciences, Vol. I, p. 301, 1900.

ST. JOHN TO GRAND FALLS.

(G. A. YOUNG.)

Miles and Kilometres

0 m.
0 km.

St. John—From St. John city, the Canadian Pacific railway runs northward for about 15 miles (24 km.) along the western side of the lower St. John, traversing in this distance a region underlain almost entirely by Pre-Cambrian strata. Leaving the St. John valley, the railroad strikes northwestward across a broken hilly country occupied by Silurian and older strata and large batholithic areas of granite.

At a distance of about 20 miles (32 km.) from the St. John valley, the railway crosses the southern border of the Carboniferous area which, terminating not many miles to the west, extends in a northeasterly direction for more than 150 miles (240 km.). Crossing the comparatively narrow southwestern extension of the Carboniferous area, the railway enters a second area of Silurian and older rocks penetrated by large bodies of granite. This broad belt of strata extends in a northeasterly direction across the province. The railway crosses it in a northerly direction and near its northwestern boundary descends into the valley of the St. John river at Woodstock which is situated on the west bank of the river.

135·1 m.
217·4 km.

Woodstock—Alt. 136 ft. (41·4 m.). At Woodstock and for many miles to the north, the St. John river is a broad, swift-flowing stream in places occupying nearly the whole width of the valley bottom, in other places bordered on one side by a flat in some cases nearly one mile (1·6 km.) wide. Everywhere the valley walls rise steeply and the general level of the country on both sides has an average altitude of between 500 and 600 feet, (150 and 180 m.). On the western side of the river, the country is plateau-like, while on the eastern side, many

isolated hills and ridges attain altitudes of above 1,000 feet (300 m.).

At Woodstock the country on both sides of the river is underlain by strata that have been classed with the Ordovician. The measures are everywhere tilted at high angles and in many places are closely folded or contorted. The strata in places are penetrated by large and small bodies of granite. Besides slates, sandstones and occasional beds of limestone, "felsites," diabase, and other fine-grained igneous rocks occur. In many places the strata are much metamorphosed and are schistose or gneissic. These or similar rocks form a wide zone extending for many miles to the northeast to the Bay of Chaleur. At one or two localities fossils possibly of Ordovician age have been found in the rocks of this assemblage. In a very few other places, Silurian and lower Devonian fossils have been found.

These "Ordovician" strata are bounded on the northwest by measures classed with the Silurian. At Woodstock, the boundary between the "Ordovician" and Silurian lies about 1½ miles (2·4 km.) to the west. This boundary, pursuing a northeasterly course, crosses the river about 10 miles (16 km.) above Woodstock.

Two miles (3·2 km.) above Woodstock, the railway crosses the St. John river to the east bank. Above this point, the Ordovician strata west of the river are confined to a very narrow strip. Along the boundary with the Silurian occur detached areas of coarse red conglomerate with some finer materials. These measures in places dip with angles as high as 60°; they have been considered to be of Lower Carboniferous age.

About 10 miles (16 km.) from Woodstock, the railway crosses the northeasterly extending boundary of the "Ordovician" and enters the Silurian which extends from this point northwards for 150 miles (240 km.), almost to the shores of the St. Lawrence. Over the many hundreds of square miles of territory that have

Miles and Kilometres.

been mapped as underlain by Silurian strata, fossils have been recovered from only a very limited number of localities. While perhaps in the majority of the cases the fossils are of Silurian age, in other cases they are definitely known to be of Devonian age. Possibly it would be more correct to consider the underlying strata of this very extensive "Silurian" area as being an assemblage of measures ranging in age from lower Devonian to Silurian or even older. The bulk of the strata are grey, calcareous slates and slate-like, impure limestones. In places heavy beds of purer limestone occur and these in some cases are fossiliferous. Beside the above mentioned rocks, grey, green and red slates, grey sandstones and conglomerates also occur and locally bodies of fine-grained, perhaps effusive, igneous rocks are present. The strata are everywhere closely folded.

147·4 m. 237·2 km. **Hartland Station**—Alt. 151 ft. (46 m.).

183·6 m. 295·5 km. **Perth Station**—Alt. 243 ft. (74 m.). At Perth, the railway crosses to Andover on the west side of the St. John. The strata underlying the country on both sides of the St. John river from Hartland to Perth, all belong to the "Silurian" and are largely grey, slaty rocks varying in composition from a slate to an argillaceous limestone.

184·8 m. 297·4 km. **Andover Station**—Alt. 257 ft. (78·3 m.). Several miles above Andover, the Tobique river joins the St. John from the northeast.

189·2 m. 304·5 km. **Aroostook Junction**—Alt. 271 ft. (82·6 m.) Just beyond Aroostook Junction, the railway crosses Aroostook river a large tributary from the west.

200·1 m. 322 km. **Ortonville Station**—Alt. 352 ft. (107·3 m.). About opposite Ortonville station, Salmon river flowing from the northeast joins the St. John. The valley of Salmon river is as deep and as pronounced as that of the St. John and has the appearance of being the northeastward continuation of the St. John valley.

Miles and Kilometres.

Five miles (8 km.) above Ortonville station, the railway leaves the river side and commences to ascend the side of the stream valley.

207·7 m. 344 km. **Grand Falls Station**—Alt. 507 ft. (154·5 m.).

GRAND FALLS, ST. JOHN RIVER.*

(G. A. Young.)

INTRODUCTION.

The St. John river both above and below Grand Falls, flows in a broad pronounced valley which in the neighborhood of Grand Falls gradually bends from a general south-easterly course above to a more nearly due south course below. Above Grand Falls, the St. John valley is probably in many places 5 to 10 miles (8 to 16 km.) wide and for a distance of about 35 miles (56 km.), the river current is comparatively feeble and the banks of the river low. Below Grand Falls, the river valley is narrower, the current swift and the stream in many places is bordered by steep banks 50 to 175 feet (15 to 50 m.) high. Both above and below Grand Falls, the St. John is bordered by river terraces but these are much more markedly developed below Grand Falls than above.

At Grand Falls the St. John river abruptly diverges from its general southerly course and swings easterly through a semi-circular course having a radius of about 2,000 feet (600 m.). In this abrupt bend of the river, the waters pour over a vertical fall of about 60 feet (18·3 m.) and, in a deep canyon beyond, descend in a series of cascades and rapids a further vertical distance of about 55 feet (17·7 m.); the total drop in this part of the river being 115 feet (30 m.). The abrupt bend in the river, the falls, the deep canyon, etc., all very obviously indicate that this portion of the river channel is of comparatively recent age, and the position of the old channel, now at least partially filled with bedded sands and gravels, is shewn in the banks of

*See Map, Grand Falls.

the river valley where the newer waterway rejoins the older.

Two geologists, Hind and Chalmers have offered explanations of the main causes whereby the St. John at Grand Falls was deflected from its original course and forced to carve out a new channel. Hind [**2**, pp. 31, 132 and 207-8] writing in 1865, believed that following the Glacial period, the whole region was submerged beneath the sea and that during this interval of submergence the St. John valley was partially filled with unconsolidated material. Subsequently as the land rose, the river cut into and removed this filling material but during this process of re-excavation, the river at Grand Falls, as it cut its way through the overburden, departed from the course of the original channel and as a result eventually carved out a new channel in solid rock.

Chalmers [**1**] in various articles, advanced the view that during the Glacial period the St. John valley was largely filled in with both stratified and unstratified material of glacial origin. After the final retreat of the glacial ice, the unconsolidated material, in places as at Grand Falls, formed dams that diverted the river from its old channel and caused it to excavate a new channel through solid rock.

The general hypothesis favoured by the writer is that during the Glacial period while the region was mantled with ice, the St. John valley was also filled with ice and comparatively little unconsolidated material was there deposited. Later, perhaps during an inter-glacial period if such occurred, but more probably during and after the final retreat of the ice, the river for a variety of causes, was overburdened with detrital material and as a consequence largely filled in the pre-existing valley. At a still later date, the river, no longer overloaded, re-excavated its ancient channel except where for perhaps minor causes, it was diverted and carved out new channels. In the case of the new channel at Grand Falls, it is thought that one factor that caused the river to form a new channel, was the existence of a deeply cut channel in the case of a minor tributary, Falls brook, coming in from the east.

Al.

Geological Survey, Canada.

Grand Falls

Feet

500 0 1000 2000

Metres

100 0 200 400 600

(Scale of map is approximate)

DETAILED DESCRIPTION.

The railway at Grand Falls station and for some distance northwards, runs on the floor of a river terrace having an altitude of 507 feet (154·5 m.). A short distance north of the station, there is on the west side of the railway tracks, a small cutting in cross-bedded sands and gravels illustrating the nature of the material in which the terraces have been carved.

About 200 yards (180 m.) north of the railway station, a road crosses the railway tracks and runs for some distance to the southwest up the slopes of the ridge bounding the St. John valley on the west. In the opposite direction, to the northeast, the road forms the principal street of the town of Grand Falls and leads to the bridge crossing the St. John river below the falls. At this road crossing, the eroded scarp of the 507-foot terrace floor on which the railway runs, is plainly visible a short distance to the west rising to a second terrace floor having an elevation of about 530 feet (161·5 m.). Beyond this another scarp is visible rising to a terrace floor having an elevation of about 560 feet (170·7 m.). Still farther up the slope of the hill which rises to an altitude of about 690 feet (210 m.), other, more faintly marked, bench-like steps occur. Besides the main terrace scarps, other much more faintly marked intermediate ones occur. These terraces were presumably formed when, after the main valley had been filled in to a height of about 600 feet (180 m.) by stratified sands and gravels, the St. John river commenced to re-excavate its valley, and they mark successively lower stages of the probably rapidly falling river level.

The 507-foot terrace floor and the scarp rising from it form the most strongly developed terrace in the neighborhood. This terrace is present on both sides of the St. John valley and extends up the valleys of the several tributaries. It also occurs in the centre of the valley surrounding the rising ground on which the town of Grand Falls is built. At the time when the river flowed over the 507-foot terrace floor it occupied two channels separated by an island now the site of the town of Grand Falls; the eastern channel eventually developed into the present channel of the river, while the western channel which

followed the course of the pre-Glacial river bed was abandoned shortly after the waters fell below the 507-foot level.

The original, pre-Glacial channel passes just east of the railway and its course is now marked by a depression crossed by a bridge at the western continuation of the main street of Grand Falls. At the bridge crossing, the elevation of the bottom of the depression is about 495 feet (150·8 m.). To the south, the bottom of the depression is nearly level, perhaps even falls a little in that direction, but farther south the bottom of the depression distinctly rises. In the opposite direction, to the north, a small stream enters the depression and flows northward with a constantly increasing gradient. This depression was perhaps outlined by the former western channel of the St. John river just before the final abandonment of this western passage. The bottom of the depression, however, rises to the south that is, downstream. This slight rise in the bed in the direction of the flow of the water may possibly only represent slight inequalities in the former river bed. The shape of the depression, on the other hand, has been obviously modified by streams tributary to the main river and perhaps it is to the action of such streams that the depression is largely or even wholly due.

Across the depression, to the east on the main street of Grand Falls, a slight rise leads to a terrace floor of the same elevation (507 feet or 154·5 m.) as that on which the railway runs. Farther on, the street rises to a higher terrace floor; beyond this the road descends to the 507-foot terrace floor whose scarp is plainly visible to the south of the road. Still farther to the east, approaching the canyon of the St. John, the road crosses other, lower terraces.

From the bridge over the St. John a splendid view is obtained of the falls at the head of the rock-walled gorge. The water enters the gorge by a vertical drop of about 60 feet (18·3 m.) and below this descends between vertical walls in a continuous series of cascades and rapids that continue down stream for a distance of 1,000 yards (900 m.), beyond which quiet water is reached. Looking westward up the river, a stream of considerable magnitude—Little river—may be seen joining the St. John just above the brink of the Falls. From the eastern end of the bridge a view may be obtained of the sharp bend of the St. John river where it leaves the course of the original channel.

Little river, the tributary entering the main river just above the falls, flows over a rock floor just before it joins the St. John and therefore, it is presumed, has also abandoned its pre-Glacial channel. This large affluent may have given rise to one of the causes whereby the St. John was led to abandon the western channel, since it is conceivable that by joining the St. John at this place, the erosive power of the eastern branch was increased over that of the western branch.

The first branch road running south, west of the bridge, joins a pathway leading to the edge of the gorge of the St. John opposite the mouth of Falls brook. This road and path pass over a terrace floor having an elevation of about 495 feet (150·9 m.). This terrace level is in places at least, rock-floored. Where the pathway approaches the edge of the gorge, it descends to a lower terrace floor having an elevation of about 450 feet (140 m.).

At the edge of the gorge, the rock walls rise almost vertical for 160 feet (49 m.). Upstream the nearly perpendicular walls are higher. Looking up the St. John from this view point, the river may be seen descending over a continuous series of cascades and rapids which abruptly cease at this place and give way to comparatively quiet waters which continue down the curving gorge to where it joins the broad stream channel of the original course of the St. John. Where this marked change in the character of the river bottom commences, there is also a change in the character of the slopes bounding the gorge. Above, the walls are nearly vertical but below, they are much less steep and in a general way are patterned like the bounding slopes of Falls brook which enters directly opposite the view point.

Falls brook at its mouth empties over a rock lip about 30 feet (9 m.) high, into the comparatively quiet waters of the St. John. Inland the bed of the brook rises about 250 feet (75 m.) in the first mile. Towards the mouth of the brook, the gradient of the stream is much less than the above average rate and when plotted in profile suggests that if Falls brook flowed with its normal gradient down the lower portion of the gorge now occupied by the St. John, it would enter the main valley of the St. John at grade. This suggestive line of evidence, together with others such as the hanging relation of Falls brook, the existence of quiet water in the lower part of the gorge of the St. John as far

up as the mouth of Falls Brook and the presence of a long series of rapids and cascades above it, and the change in the character of the valley walls at the mouth of Falls brook, indicates that the lower part of the gorge of the St. John was once part of the valley of Falls brook and that this portion of the valley is of pre-Glacial age. The existence of this valley appears to have been one of the factors that caused the St. John to carve out its new valley. In doing this the St. John lowered the original gradient of the lower part of Falls brook so that the valley of this brook is now a hanging valley. Where the St. John entered the valley of Falls brook, a fall was established which has since receded to its present position, 2,800 feet (850 m.) upstream. Eventually these falls may retreat as far as the pre-Glacial site of the river above the falls. If this should occur, the St. John would speedily re-excavate the upper portion of its course.

The exit of the gorge of the St. John may be seen from the top of the steep banks overlooking the river about 200 yards (180 m.) east of the railway station. This view point is situated close to the western slope of the old valley of the St. John for a succession of rock ledges outcrop along the western shore and bounding slopes that stretch in a straight line to the south. To the east, distant about 600 yards (550 m.), the rock-walled mouth of the gorge of the St. John is visible where it enters at right angles into the older course of the St. John still occupied by the river. Between the rock cliffs at the mouth of the gorge on the east and the steep slopes on the western side, there runs a curving escarpment convex towards the north whose crest lies about 200 feet (60 m.) above the waters of the St. John. This escarpment has been formed in the unconsolidated material filling the abandoned portion of the river channel. The upper part of this escarpment is cliff-like and is there seen to be composed of bedded sands and gravels. The lower, greater part of the escarpment is mantled by talus and the nature of the material occupying the lower part of the old valley cannot be directly determined. It is assumed that it is of the same character as that filling the upper portion. That the thickness of this material is no greater than the height from the level of the St. John waters to the top of the escarpment, is indicated by the outcrops of rock occurring at the foot of the talus slope along the side of the river. These rock outcrops are

evidently a portion of the rock floor of the abandoned pre-Glacial channel.

Bibliography.

1. Chalmers, R. Geol. Surv. Can., Report of Progress for 1882-83-84, part GG., pp. 12-13, 35-37, 1885.
   " " Geol. Surv. Can., Annual Report, Vol. I, Part G.G., pp. 38-39, 1886.
   " " Geol. Surv. Can., Summary Report for 1894, p. 82, 1895.
   " " Geol. Surv. Can., Summary Report for 1899, p. 149, 1900.
   " " Geol. Surv. Can., Summary Report for 1900, pp. 152-53, 1901.
2. Hind, H. Y. Preliminary Report on the Geology of New Brunswick pp. 31, 132, 207-8, Fredericton, 1865.

ANNOTATED GUIDE.

GRAND FALLS TO RIVIÈRE DU LOUP.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km. **Grand Falls**—Alt. 507 ft. (154·5 m.). About 1 mile (1·6 km.) above Grand Falls the Canadian Pacific railway crosses the river to the eastern side along which it runs to Edmundston. The country bordering the St. John is hilly though few of the hills are of any considerable elevation. Approaching Edmundston the country begins to be rugged. Very few rock exposures occur along the river and these in most cases are dark slates. At one locality a few fossils have been found of about Niagara age, but the strata in general have been considered to be late Silurian or early Devonian.

38·7 m.
62·3 km. **Edmundston**—Alt. 468 ft. (142·6 m.). From Edmundston, the Temiscouata railway runs northwestward up the valley of Madawaska

Miles and Kilometres.

river, one of the larger tributaries of the St. John. The valley of the Madawaska is flat-bottomed and rock exposures are rare. Such outcrops as occur are of dark slate of Silurian age.

59·3 m.
95·4 km.
Ste. Rose Station—Alt. 504 ft. (153·6 m.). About $1\frac{1}{2}$ miles (2·4 km.) beyond Ste. Rose station, the railway approaches the foot of Temiscouata lake, out of which the Madawaska river flows. The railway for a number of miles closely follows the southwestern shore of the lake. Temiscouata lake is about 24 miles (38·6 km.) long and varies between 1 and 2 miles (1·6 and 3·2 km.) in width.

The strata along the shores of the southern part of the lake consist of tightly folded and contorted dark grey slates and argillaceous limestones with occasional beds of sandstone. These measures are of Silurian age and are exposed in a number of cuttings along the railroad.

68·1 m.
109·6 km.
Notre Dame du Lac Station—Alt. 517 ft. (157.6 m.). The folded crumpled dark slates occur in a number of cuttings along the railway for about 3 miles (4·8 km.) beyond Notre Dame du Lac station. Beyond this for a distance of several miles occurs a thick series of strata in places containing fossils of Niagara or perhaps Clinton age. The series in part consists of slates and sandstones, in part of fine-grained tuffs and volcanic conglomerates. The volcanic strata consist of slightly waterworn fragments of andesite, devitrified glass, etc. The same strata are repeated on the northeastern shore of the lake.

76·3 m.
122·8 km.
Cabano Station—Alt. 500 ft. (152·4 m.). On the northeast shore, opposite Cabano, Mount Wissick rises 550 feet (167·6 m.) above the lake, to an altitude of 1,035 feet (315 m.). Mt. Wissick is formed of Silurian strata dipping to the southeast at angles of 15° to 70°, and these measures there yield a section of above 1,950 feet (595 m.) of strata which in places are richly fossiliferous and have been described as

Miles and Kilometres.

being of uppermost Silurian or lowermost Devonian age. These measures along the northern base of Mount Wissick repose on strata of the Quebec group over which it seems likely they have been thrust.

A short distance beyond Cabano, the railway swings away from the lake and following a westerly direction crosses the boundary of the Silurian area about 2 miles (3·2 km.) west of Cabano. From this point the railway crosses the zone of the Quebec group strata that borders the lower St. Lawrence, and which at this point has a width of about 30 miles (48 km.). These measures are usually vertical or steeply inclined to the south suggesting that the strata for the greater part occur in a series of overturned anticlines. The beds occur in alternating bands of grey sandstones and grit, and grey, green and red slates. These measures have been classed with the Sillery and considered to be of Cambrian age. Possibly, however, other strata are present. The strata are exposed in numerous cuttings along the railway.

Westward from Cabano, the railway ascends through a country occupied by long low ridges and hills and 19·3 miles (31 km.) from Cabano station crosses a summit level having an altitude of 1,324 feet (403·5 m.). Beyond this, the railway gradually descends through a less broken country to the lower levels bordering the St. Lawrence.

119·6 m. 192·5 km. **Rivière du Loup**—Alt. 316 ft. (96·3 km.). Rivière du Loup is the junction point of the Temiscouata railway and the Intercolonial railway.

234·1 m. 376·7 k.m. **Lévis**—For description of route from Rivière du Loup to Lévis via the Intercolonial Railway, see pages 52-56.

396·9 m. 638·7 k.m. **Montreal**—For description of route from Lévis to Montreal via the Intercolonial Railway, see pages 24 and 25.

513·1 m. 825·7 k.m. **Ottawa**—

GUIDE BOOK No. 2

EXCURSIONS

IN

The Eastern Townships of Quebec and the Eastern Part of Ontario.

(EXCURSIONS A 2, A 5 AND A 9.)

ISSUED BY THE GEOLOGICAL SURVEY

h.

OTTAWA
Government Printing Bureau
1913

Geological Survey, Canada.

Route map between **Montreal**, **Ottawa**, **Kingston**, and **Toronto**.

Miles: 25 0 25 50 75 100

Kilometres: 25 0 25 50 75 100 125 150

GUIDE BOOK No. 2

Excursions in the Eastern Townships of Quebec and the Eastern part of Ontario

CONTENTS.

35064—1½

Corundum crystal, (Natural size.)
Craigmont, Ont.

EXCURSION A 2.

THE HALIBURTON-BANCROFT AREA OF CENTRAL ONTARIO.

BY

Frank D. Adams
AND
Alfred E. Barlow.

CONTENTS.

INTRODUCTION.

This excursion has been arranged to enable members of the Twelfth International Geological Congress to see a typical Pre-Cambrian area in Eastern Canada.

Like other parts of the Canadian Shield, this area is strikingly different in physiographic character from the great Paleozoic plain which lies to the south and west. It is a rough and rugged country, supporting a more or less scattered farming population, but still largely forest-clad, especially in its northern portion. The Pre-Cambrian in this portion of Central Ontario probably presents a greater variety of rock types than has yet been described from any similar area of ancient cyrstalline rocks in North America. It shows in a striking manner the progressive metamorphism of the Grenville-Hastings series resulting from Laurentian batholithic intrusions. These limestones, together with their associated paragneisses and amphibolites—the Grenville-Hastings series—are regarded as the greatest accumulation of Pre-Cambrian sediments in North America.

This area also contains a very extensive and remarkable development of nepheline rocks, among which are many rare and some unique types. These present, in places,

the phenomenon of the crystallization of a magma supersaturated with alumina, the excess of which has separated out in the form of corundum, forming deposits of this mineral of economic value, which have been extensively worked. These nepheline rocks occur almost without exception along the border of the granitic batholiths when the latter come against the limestone series.

HISTORY OF GEOLOGICAL EXPLORATION IN THE LAURENTIAN OF EASTERN CANADA.

When Mr. W. E., afterwards (1856) Sir William, Logan, of the Geological Survey of Canada, made an examination in 1844 of the region bordering the Ottawa river, he found great areas underlain by very ancient foliated crystalline rocks. These seemed to him, on further study, capable of subdivision into two conformable series, which he subsequently (1853) called the "Laurentian series." This designation was proposed by the fact that these rocks constitute the bulk of the "Laurentide Mountains," a name suggested by F. X. Garneau, the historian of Quebec, for that great stretch of rocky country which forms the highlands to the north of the River and Gulf of St. Lawrence. This sharply defined series of elevations is not strictly a mountain range, but merely the steep margin of the great rocky plateau of the Canadian Shield.

Logan's lower or older group consisted exclusively of "syenitic gneiss showing no end to the diversity of arrangement in which the minerals and the colours will be observed, but there is a never-failing constancy in respect to their parallelism. But this, though never absent, is sometimes obscure." These rocks were supposed by Logan to form a low anticlinal arch in the region extending from Mattawa river to the vicinity of Montreal river on Lake Temiskaming. The upper group is stated to crop out in the district south of Mattawa and Ottawa rivers and to be characterized "by the presence of important bands of limestone which have undergone extensive crystallization as a result of extreme metamorphism," while the different gneissic rocks which separate the various bands of

limestone "differ in no way either in constituent quality or diversity of arrangement from the gneiss lower down."

Subsequently this lower gneiss was called the "Ottawa Series" while the upper group, differentiated in the first place solely on account of the presence of the limestones, was included under the name Middle Laurentian or "Grenville Series." He afterwards found in Eastern Ontario a series of rocks which he considered in all probability to represent the Grenville series in a less altered state and to this he gave the name of the "Hastings Series." The foliation of the gneisses was regarded by him as the survival of an almost obliterated bedding. The name Upper Laurentian was given to a terrane formed chiefly of anorthosites which were afterwards shown to be of irruptive origin, and with which were classified by mistake certain gneiss and limestone bands identical in character with those included as the Grenville series, to which they clearly belong. For many years very little light was thrown upon the relations of the Grenville series and the Ottawa series or "Fundamental Gneiss" as it was frequently called. The relationship of the Grenville and Hastings series also remained a matter of uncertainty.

In 1885 Dr. Andrew C. Lawson showed the presence in the region north-west of Lake Superior of great bodies of foliated granitic rocks forming the base of the geological column and the equivalent of the "Fundamental Gneiss" of Logan. This gneiss, as Lawson conclusively demonstrated, is intruded through the oldest sedimentary rocks (Keewatin group) of that region in the form of great batholiths. This work marked an epoch in the interpretation of Pre-Cambrian geology not only in Canada but in all North America.

Then followed, in 1893, Adams' demonstration that Logan's "Upper Laurentian" did not exist as an independent geological series, the anorthosites, which were considered as constituting its main features, being in reality great intrusive masses. In a subsequent (1895) paper he showed that two distinct classes of rocks could be distinguished in the remaining portion of the Laurentian, the first being beyond all doubt igneous rocks and the second consisting of highly altered rocks of aqueous origin.

From the results of these investigations, it became evident that if a satisfactory knowledge of the origin, character, structure and relations of the Laurentian

Sketch-map, showing the position of the Haliburton and Bancroft areas in relation to the Laurentian Highlands, etc.

succession in Eastern Canada was to be obtained, it would be necessary to select some large area of these rocks and map it in much greater detail than had hitherto been attempted, the examinations in the field being supplemented by thorough petrographical study of the various rock types represented in the area. The area selected for such detailed study was that designated as Sheet No. 118 (Haliburton sheet) of the Ontario series of geological maps which are being issued by the Geological Survey of Canada. As will be seen by the accompanying sketch map, this district lies close to the margin of the great Northern Protaxis, north of Lake Ontario and to the east of Georgian bay.

Dr. Frank D. Adams, with whom Dr. Alfred E. Barlow was subsequently associated, undertook for the Geological Survey a detailed geological study of this region, concerning the geological structure of which nothing was known at that time but which, from its position, promised to yield valuable results if carefully studied. During the progress of this work it became evident, if the substantial results expected were to be realized, that the work should be extended to cover the district lying to the south-east of the Haliburton sheet. This was accordingly done and two maps were prepared; one, the Haliburton sheet, on a scale of four miles to an inch (2·53 km. per cm.), and the other, embracing the south-eastern portion of the Haliburton sheet and the district lying to the south-east, on a scale of two miles to an inch, (1·27 km. per cm.), which was designated as the Bancroft sheet. The Haliburton map-sheet embraces an area of 3,456 square miles (8,600 sq. km.); the Bancroft map-sheet 1,955 square miles (4,900 sq. km.); and the two map-sheets together cover 4,200 square miles (10,500 sq. km.) The field and accompanying laboratory work occupied a period of about eight years, the results being embodied in Memoir No. 6 issued by the Geological Survey of Canada in 1910. [**1.**].

PHYSICAL FEATURES OF THE AREA.

The general character of the surface of the area is uniform throughout its entire extent. The country is a great uneven plain which may be called a peneplain,

Laurentian peneplain, looking east from Fort Stewart, township of Carlow.

although this term implies that it has had its origin in long continued processes of sub-aerial denudation. In how far these processes have contributed to the formation of the plain or have been assisted by marine erosion are questions which remain unanswered.

The depressions in the surface of the country give it a decidedly hilly or rolling appearance, but its character as a great peneplain is at once recognized when the landscape is viewed from any of the higher points in the area, when the sky-line will be seen to be flat and even around the whole horizon, its uniformity being rarely interrupted by low monadnocks. It is impossible on this excursion for the party to visit any of the highest points in the area, but the even character of the skyline to the north and east will be seen from a point on lot 29, con. IV in the township of Glamorgan. But, while the plain appears very even, viewed from any one point of outlook, it is not quite horizontal. From the south-western part of the area, where this plain emerges from underneath the Palaeozoic cover, it gradually rises toward the north and attains a maximum elevation of 1,500 feet (457 m.) above sea level near the northern limit of the Haliburton sheet, the gradient in this interval being from 6½ to 8 feet per mile (1·24 to 1·52 m. per km.). The depressions in the surface of the plain are shallow. It is very unusual indeed, in any part of the area, to find hills whose summits (representing the surface of the plain) rise as much as 200 feet (61 m.) above the river or lake at their base.

One of the most characteristic landscape features of this region, as of most other parts of the great Northern Protaxis in Canada, is the immense number of lakes, great and small, which are scattered over its surface. Some 525 lakes occur in the area of 4,200 square miles (10,500 sq. km.) embraced by the Haliburton and Bancroft map-sheets, that is to say, there is on an average one lake to every eight square miles of surface. These lakes range in size from comparatively large ones, like Hollow lake, which has an area of 22 square miles (55 sq. km.), to small ponds which cover only a fraction of a square mile. They discharge in a multitude of streams which, with the lakes, form a wonderful series of waterways by means of which, it is possible to traverse the area by canoe in almost any direction, without making portages of any great length.

These lakes either occupy true rock basins or depressions in the mantle of drift or they have banks formed in part by rock and in part by drift, occupying in some instances portions of a larger rock basin which has been partitioned off by masses of drift.

Over the greater part of the area the drift is comparatively thin, so that, while it forms the soil of the country, the underlylng rock in the form of smooth *roches moutonnées* protrudes through it at frequent intervals. On the higher levels the drift is unstratified and filled with boulders. Stratified sands and gravels, however, are found around the lakes and in the river valleys.

A glance at the Haliburton sheet will show the remarkable influence which the strike of rock underlying the area has had upon the distribution and position of the lakes and upon the courses of the streams. In the southern portion of the area these follow very closely the course of the bands of Grenville limestone, while in the granitic region of the north they form a delicately etched pattern on the surface of the great plain of granitic gneiss, occupying shallow depressions whose course is determined chiefly by the strike of the country rock; and even when the lake runs across the strike, the long arms and bays in its deeply indented shore line will be found to follow the directions of the foliation.

GEOLOGY OF THE AREA.

The Haliburton and Bancroft map area is a very typical Archean or Pre-Cambrian area, near the southern margin of the Canadian Shield or great Northern Protaxis which stretches with almost unbroken continuity to the borders of the Arctic ocean. Ordovician strata, which survive as evidence of the transgression of the Palaeozoic sea from the south occur as isolated outliers of various sizes and shapes. They form conspicuous steep-faced hills of horizontally stratified rocks in the townships of Lake, Methuen, Burleigh and Harvey, in the south-west angle of the Bancroft sheet. To the south of Stony lake, the northern portions of Dummer and Smith townships are forms by the main body of the Ordovician which forms the great plain stretching southward to Lake Ontario and beyond.

The line of contact between the highly inclined crystalline rocks of the Pre-Cambrian and the horizontal limestones and sandstones of the Palaeozoic is marked by a very distinct and abrupt change in the character of the country. The Pre-Cambrian region is decidedly rocky and uneven and is thus in large part unsuited for purposes of agriculture. It is pre-eminently a grazing country with great streches of uncleared forest land still remaining. In marked contrast the country underlaid by Ordovician strata is prevailingly flat and fertile, well cleared, and occupied by a large farming population.

As shown by the accompanying geological maps, the Laurentian country is underlain by a diversified series of altered sedimentary rocks among which limestones predominate, resting upon and invaded by enormous bodies of gneissic granite.

The sedimentary series is largely developed to the south-east where it is comparatively free from igneous intrusions. Towards the north-west, however, the granite, in ever-increasing amount, arches up the sedimentary series and wells up through it, in places disintegrating it into a breccia composed of shreds and patches of the invaded rock scattered through the invading granite, until eventually connected areas of the sedimentary series disappear entirely and over hundreds of square miles the granite and granite-gneiss alone are seen, holding, however, in almost every exposure, inclusions which represent the last scattered remnants of the invaded rocks. The type of structure presented by the invading granite is that of a batholith. The term batholith is used in the sense in which it was employed by Lawson in his classic work on the Lake of the Woods and Rainy Lake districts, to designate great lenticular or rounded bosses of granite or granite-gneiss which are found arching up the overlying strata through which they penetrate, disintegrating the latter, and displaying at the same time a more or less distinct foliation, which is seen to conform in general to the strike of the invaded rocks when these latter have not been removed by denudation.

I.—The Invading Batholiths.

The batholiths of the area are well shown on the Bancroft sheet, and have a general trend in a direction

about N. 30° E., which is also the direction in which the area is folded. They occur isolated or in linear series so arranged that a very small amount of additional erosion, by removing the intervening cover, would evidently convert the series into a single, long, narrow batholith.

Within the batholiths themselves the strike of the foliation follows sweeping curves, which are usually closed and centred about a certain spot in the area where the foliation becomes so nearly horizontal that its direction and even its existence, where the surface is level, becomes difficult to recognize. From these central areas of flat-lying gneiss, the dip of the gneiss (where it can be determined) is usually found to be outward in all directions. The batholiths are, therefore, undoubtedly formed by an uprising of the granite magma from below, and these foci indicate the axis of the greatest upward movement. These centres are not all areas of more rapid uplift. On the contrary, the gneissic foliation in some cases dips inward in all directions towards the centre, thus marking them as places where the uprise of the magma was impeded, that is to say, places where the overlying strata have sagged down into the granite magma.

If this district presents the basement of a former mountain-range, now planed down, the direction of this mountain range was about N. 30° E., or, in a general way, parallel to the course of the valley of the St. Lawrence.

The movements in the granite to which reference has been made did not take place solely while the rock was in the form of an uncrystallized or glassy magma. They continued as the rock cooled and while it was filled with abundant products of crystallization, the movement being brought to a close only by the complete solidification of the rock. Evidence of protoclastic structure can therefore be seen throughout all the areas coloured as granite or granite-gneiss on the map, except in the case of a few small bodies of granite apparently of more recent age. This protoclastic structure is marked by the presence of more or less lenticular, broken fragments of large individuals of the feldspar, in a fluidally-arranged mosaic of smaller allotriomorphic feldspar grains with quartz strings and a few biotite flakes. This fluidal arrangement, which constitutes the foliation of these rocks, is seen in every stage of development, there being an imperceptible gradation from the perfectly massive forms occasionally seen,

through the more or less gneissic varieties, to thinly foliated gneisses. It is impossible to separate the several varieties. They constitute progressive developments of one and the same structure, and are different phases of one and the same rock mass.

The granite-gneiss is undoubtedly of igneous origin, is very uniform in its mineralogical composition, and differs distinctly from the sedimentary gneisses (paragneisses) of the area. It is medium to rather fine in grain, and composed almost entirely of quartz and feldspar, the latter preponderating. Biotite is present in very subordinate amount. The rock in the southern batholiths occasionally contains a little hornblende. While the feldspar is always reddish in colour, a large proportion of it is really an acid oligoclase. The rock would ordinarily be classed as an albite-granite or granite-gneiss, and, although the soda feldspar preponderates, should be so classed, since it resembles a granite in every respect.

Two analyses of typical specimens of this granite are tabulated below:—

—	I. Per cent.	II. Per cent.
SiO_2	73·33	76·99
TiO_2	0·17	....
Al_2O_3	13·55	12·45
Fe_2O_3	0·58	1·03
Feo	1·53	0·49
MnO	0·04	tr.
CaO	1·66	0·98
MgO	0·45	0·21
K_2O	3·12	4·29
Na_2O	5·01	3·46
CO_2	....	None.
H_2O	0·45	0·26
Totals	99·89	100·16

I. Gneiss, Township of Methuen, Lot 17, Range V. (M. F. Connor, analyst.)

II. Gneiss, Township of Livingstone, Lot 10, Range V. (N. Norton-Evans, analyst.)

No. I consists of microcline and plagioclase, with small amounts of quartz and of an untwinned feldspar, as well as very subordinate amount of biotite and hornblende. It is impossible in the case of this analysis to calculate the exact proportions of the iron-magnesia constituents which are present, on account of the fact that the exact composition of these minerals is not known. The 'norm,' however, is given below. By this is meant the calculation of the analysis into the form of certain standard minerals, showing the mineralogical composition of a rock into which such a magma might crystallize under slightly different conditions [**3**, p. 47]. The norm represents in this case very nearly the true percentage of the various minerals present, although diopside and hypersthene are calculated as present, which are represented by other combinations in the actual rock. It is as follows:—

Orthoclase	18·35
Albite	42·44
Anorthite	5·28
Quartz	27·72
Diopside	2·57
Hypersthene	1·92
Magnetite	0·93
Ilmenite	0·30
Total	99·51

In this rock the albite and anorthite shown in the analysis are combined in an acid plagioclase which exceeds in amount the potash-feldspar, a fact which is also shown by separations with Thoulet's solution. The rock takes its place in the quantitative classification as a lassenose.

No. II is seen under the microscope to be composed essentially of feldspar and quartz, with a small amount of biotite. Untwinned feldspars, apparently orthoclase and microcline, are present in large amount, and the proportion of feldspar grains showing the ordinary albite-twinning is small. A little iron ore and a very few minute individuals of apatite and zircon complete the list of constituents present. A separation of the constituents of the rock by means of Thoulet's solution showed that the amount of oligoclase present was considerably greater than that of orthoclase and microcline taken together, a conclusion confirmed by the analysis. This, when calculated out,

shows the rock to have the following percentage composition (mode):—

Orthoclase	25·58
Albite	29·34
Anorthite	5·00
Quartz	37·68
Biotite	0·90
Magnetite	1·39
Water	0·26
Total	100·15

It will thus be seen that the amount of anorthite present is sufficient, when united with the albite, to give 34·34 per cent of an acid oligoclase having the formula Ab_6 An, thus bearing out results obtained by the Thoulet separation. This combination as compared with the orthoclase, is present in about the proportion of 3 to 2. This rock, in the quantitative classification, is a tehamose.

Dark inclusions are present throughout the granite-gneiss almost everywhere in the area. These are often very abundant, and consist of amphibolite or closely allied rocks. In some places, on account of their abundance and angular character, the granite presents the appearance of a breccia. These fragments, while usually more or less angular, have sometimes been softened and drawn out in the direction of the movement of the gneiss so as to impart to the rock a streaked or banded appearance. In other places, the inclusions have been so completely permeated by the granite-magma that they are utterly disintegrated. Every stage of passage from the sharply angular inclusions to the final products of disintegration can be traced in many places, although in most cases the inclusions are well marked and sharply defined against the enclosing gneiss. At many points throughout the red granite-gneiss of the batholiths, moreover, streaks of grey gneiss are found. It is estimated that, taking the granite-gneiss of the whole area examined, the amphibolite inclusions represent about 10 per cent of its volume and this grey gneiss another 10 per cent.

The origin of these amphibolite inclusions and of the masses of grey gneiss is not only a question of much interest, but one of considerable importance to the true understanding of the geological processes which have been

at work in this region. As is well known, similar inclusions of dark basic rocks of the nature of amphibolite are found in very many occurrences of granite, especially those of Pre-Cambrian age, in various parts of the world, and they have been the subject of much investigation and widespread discussion. By many geologists they have been considered to be basic differentiation products from the acid magma, while others have looked upon them as fragments of foreign rocks caught up by the granite.* In the region at present under discussion there are three ways in which it would be possible to consider them as having had originated:—

(1) As the basic differentiation products (Ausscheidungen) from the granite magma.
(2) As portions of the rock forming the walls or roof of the batholith, which had fallen into the granite magma and had partaken of its subsequent movements.
(3) As fragments of intrusive masses, dykes, stocks, etc.

A careful study of all parts of the area has failed to furnish any evidence that the first is the true explanation anywhere. There is positive proof that the second is the correct and only explanation of the inclusions in several parts of the area, and it is an explanation not opposed to the facts in any part of the area. The inclusions in some places, more especially in the great northern granite-gneiss areas, may have originated in part as set forth in the third explanation. The form of the inclusions sometimes suggests this; but the movements in the granite have been so great, and the inclusions have been so torn to pieces, that it has been impossible to decide whether any of them have been derived from the source indicated under this head.

*C. H. Smith, Jr., 'Report on the Crystalline Rocks of St. Lawrence County, N.Y. State Mus. 49th Ann. Rep. 1895, vol. ii (1898), p. 490. The black inclusions in the granite-gneisses of the Adirondacks are considered to be broken masses of an older rock caught up by the granite-gneiss when the latter was still in a molten condition. B. Frosterus. 'Bergbyggnaden i Sydostra Finland', Bull. Comm. Geol. Finl. vol. ii. No. 13 (1902), p. 157, considers that the amphibolites, which are characteristic associates of the granite-gneiss of Southern Finland, are probably for the most part altered dyke-rocks. Some of them still show a gabbro-like structure. which, if the granite be supposed to represent the original subcrust in a softened or remelted condition, cut through this crust, and were connected with basic effusives at the surface: these masses, having been torn to pieces by the subsequent movements of the softened granite, now appearing as scattered fragments.

II. Rocks of Sedimentary Origin.

(a) *Limestones.*

The limestones in this Laurentian area are very thick, and underlie a large part of it. In their more altered form they closely resemble those described by Logan in the areas examined by him; but to the south-east of the Bancroft sheet, where the invading granite is less abundant and the alteration of the invaded strata is correspondingly less pronounced, the limestones appear in less altered forms, and eventually pass into fine-grained, greyish-blue varieties in which the bedding is perfectly preserved and concerning whose truly sedimentary character there can be absolutely no doubt. It is impossible to represent on the map the gradual transition of the comparatively unaltered blue limestones into the coarsely crystalline white marble. This, however, takes place by the development in the former of little strings or irregular patches of coarsely crystalline white calcite, usually following the bedding-planes. These become larger and more numerous on going north in the area towards the granite intrusions, until eventually the whole is transformed into a great development of white marble. Here and and there through the marble, where the bodies of the rock are very thick, small remnants of the original blue limestone can occasionally be found, as is indicated on the map in the township of Monmouth.

Enormous bodies of nearly pure limestone occur in many parts of the area; but elsewhere this limestone is impure, owing to the presence of grains of various silicates distributed through it, or to the presence of little bands of silicates representing impurities in the original limestones, which, under the influence of metamorphism, develop into gneisses and amphibolites of various kinds. Where these little gneiss bands or amphibolite bands become increasingly abundant, the limestone passes over into paragneiss or into some one of the varieties of amphibolite.

(b) *Quartzites.*

Quartzite is not common in this area, the most extensive development being that which occurs as a band crossing the township of Monmouth. It is found interstratified with crystalline limestones and rusty-weathering gneisses of sedimentary origin.

Interbanded crystalline limestone and granular amphibolite. Wellington road, lot 6, Con. III, Chandos township.

Interbanded crystalline limestone and granular amphibolite, Wellington road, lot 6, Con. III. Chandos township.

There is every reason to believe that these quartzites represent, in most cases at least, altered sandy sediments.

(c) *Gneises of Sedimentary Origin* (*Paragneisses*).

These rocks differ distinctly in appearance from the foliated granite- gneisses already described as constituting the batholithic intrusions. They are fine in grain, and show no protoclastic or cataclastic structure, the original material having been completely recrystallized. They have, therefore, an allotriomorphic structure with a tendency for certain of the constituent minerals to be elongated in the direction of the original bedding. While quartz, feldspar and biotite are among the constituents present, the mica is usually more abundant than in the granite-gneisses. In addition to these, garnet, sillimanite, graphite and pyrite are very frequently present, the oxidation of the last mineral giving rise to a prevailingly rusty colour on the weathered surface. These gneisses occur in well-defined beds, and are usually found intimately associated with the limestones. They resemble in many ıespects the hornstones which are found in granite contact-zones, but are rather more coarsely crystalline than is usual in this class of rocks.

III.—Amphibolites.

Intimately associated with these sedimentary gneisses and the limestones on the one hand, and with the gabbros and diorites on the other, is another class of rocks which is grouped under the name of amphibolite. While many varieties of these rocks occur in the area, differing considerably one from the other in appearance, they have in common a dark colour and a basic composition. Quartz, one of the commonest constituents in the gneisses, is absent or is present only in very small amount; while hornblende and feldspar, the latter chiefly plagioclase, are the main constituents of the rock. Pyroxene and biotite often replace the hornblende in part.

These rocks underlie large areas, as represented on the Bancroft sheet. They also occur as interbedded layers so intimately associated with certain developments of the limestones that these limestone-amphibolite occurrences have been mapped separately. In places the sedi-

mentary gneisses also fade away into occurrences of amphibolite when traced along the strike. Masses of amphibolite also abound as inclusions throughout the granite of the batholiths.

These amphibolites are not peculiar to this area, but occur abundantly everywhere in the Laurentian. They have always proved to be one of the chief difficulties in the way of a correct understanding of the geology of this system, seeing that it has been impossible to do more than indulge in conjectures concerning their origin. The same difficulty has been encountered in the case of these and allied rocks occurring elsewhere, as, for instance, the trap-granulites of the Saxon Granulitgebirge or the amphibolites of the crystalline complex of certain portions of the Alps, the origin of which remained in doubt, while that of the rocks wherewith they were associated had been definitely determined.

Two of the more common varieties of these amphibolites are represented by special designations on the map. One of these, which has been termed "feather-amphibolite," always occurs in thin bands interstratified with limestone, and derives its name from the curious feather-like development displayed by large skeleton crystals of hornblende or pyroxene which appear on the plane of stratification of the rock, to which they give a striking appearance when it is split along this direction. The other variety of amphibolite, which also frequently occurs as heavy bands in the limestones, is of a finely granular character without very distinct foliation. On weathered surfaces it presents a uniformly, minutely speckled appearance, owing to the intimate admixture of the minute grains of hornblende and feldspar. On this account, during the prosecution of the field-work, this variety was designated as 'the pepper-and-salt amphibolite', and in the legend of the Bancroft sheet it is designated as granular amphibolite.

Still other varieties differ from this granular amphibolite, in being somewhat coarser in grain or less regular in composition.

As the result of a very careful examination, it has been possible to prove conclusively that in this area the amphibolites have originated in three entirely different ways, the resulting rocks, although of such diverse origin, often being identical in appearance and composition. This

Weathered surface of feather amphibolite, township of Wollaston.

remarkable convergence of type, whereby rocks of widely different origin come to assume identity of character, explains the difficulty which has been experienced up to the present time in arriving at a satisfactory conclusion concerning their genetic relations.

(a) Some of these amphibolites result from the metamorphism and recrystallization of sediments. To this class belong the feather-amphibolites above described, which usually occur in thin bands alternating with crystalline limestone, and are evidently of like origin. They represent siliceous or dolomitic laminae in the calcareous deposit. In many cases the bands of crystalline limestone become thinner and less abundant, and the composite rock passes gradually over into a body of pure feather-amphibolite. Whether the granular amphibolite, which is also found alternating with bands of limestone very frequently and over wide areas, is in some cases of similar origin, it has not been possible up to the present time to decide.

(b) Certain granular amphibolites represent altered igneous intrusions, for they are found in the form of dykes cutting across the stratified white crystalline limestone on the shores of Jack's lake in the township of Methuen. The limestones here dip at a low angle to the south, and are excellently exposed in low cliffs about the lake. The typical granular amphibolite can be seen rising above the surface of the water in the form of vertical dykes one to two feet (·3 to ·6 m.) wide which cut directly across the stratification of the limestone. These can frequently be seen to have been diverted along certain bedding-planes and torn apart by movements in these planes, the limestone-strata having experienced somewhat extensive movements along their bedding-planes during their upheaval. The dykes, after following the bedding-planes for a certain distance, once more cut vertically across them and so reach the surface. Such dykes when seen on limited exposures of the bedded surface of the limestone, especially in contorted districts, would usually present the appearance of interstratified masses of amphibolite.

This amphibolite has the regular allotriomorphic structure of a completely recrystallized rock, and differs from any of the normal igneous rocks. Under the microscope it is identical with an amphibolite described by Dr. Teall, which was developed by the alteration of a diabase

dyke where crossed by a line of shearing. In the case of these Canadian dykes, however, the amphilbolite is not confined to that portion which has been clearly subjected to movement, but forms the whole mass of the dyke.

(c) Amphibolites which are identical in physical character and in composition with those described under (b) are also produced by the metamorphic action exerted by the granite-batholiths on the limestones through which they cut. This is a remarkable fact, and one which at first sight seems scarcely credible. It is, however, a change which has undoubtedly taken place on a large scale.

In addition to the amphibolites which have originated in the three ways above mentioned, it is highly probable, judging from their character and mode of occurrence, that the amphibolite bands associated with the large gabbro and diorite masses—as, for instance, that running in a north-easterly and south-westerly direction through the township of Wollaston, and that extending from the south-eastern portion of the township of Cardiff, into Anstruther—represent highly altered basic volcanic ashes and lava-flows, connected with vents represented by the gabbro-stocks. The latter of these amphibolite bands presents a great variation from place to place in the character of the constituent rock. While in some places it is well banded, elsewhere it is streaked or presents an appearance strongly resembling flow-structure, with lighter coloured lath-like forms highly suggestive of feldspar phenocrysts thickly scattered through it. Yet elsewhere the appearance suggests an original amygdaloidal structure. The rock, however, is so completely recrystallized, that a microscopic examination does not yield any conclusive evidence concerning its original character.

IV. Gabbros and Diorites.

These rocks differ from the amphibolites in that they are massive and usually coarse grained. They also differ in their mode of occurrence as great basic intrusions. While some of these intrusions are pretty uniform in character, others display a very marked differentiation and present many petrographical varieties within a single intruded mass.

Many of them, in addition to pyroxene, a basic plagioclase and iron ore, hold a large amount of hornblende

and may be described as gabbro-diorites although the character of the hornblende frequently suggests its derivation from augite under the action of metamorphic agencies.

V. Nepheline and Alkali Syenites.

The nepheline and alkali syenites constitute one of the most interesting and important groups of rock in the whole area. One of their most notable characteristics is that they usually display a well marked foliation which coincides in direction with that of the gneissic granites of the Laurentian with which they are associated, and with which they are believed to have a close genetic connection. They occur almost invariably throughout the area, as a border facies of the granites where these come against the limestones of the Grenville series, and are intrusive into the latter rocks with which along the contact they are frequently intimately interbanded. The nepheline syenite magma has apparently transfused the limestones, of which it holds many inclusions, so that a certain amount of calcite, occurring as inclusions in some cases and in all cases of undoubtedly primary origin, is found in almost every occurrence of the nepheline syenite

This group of rocks results from the crystallization of magma rich in alkalies and alumina. The resultant rock types present many varieties of nepheline rock (free or almost free from feldspar), nepheline syenite and alkali syenites, each accompanied by corresponding pegmatitic developments. The magma was in all cases very rich in soda as shown not only by the presence of nepheline but also by the fact that the feldspar present in the rocks is almost always albite. Even in the syenites free from nepheline, this soda feldspar usually predominates very largely, although in some cases the corresponding potash feldspar is the dominant constituent. These rocks are as a general rule very poor in ferro-magnesian constituents, the latter when present being represented by either biotite or hornblende, or by both.

The occurrence of corundum in great abundance in these nepheline rocks, more especialy in the eastern portion of the area, gives to them a peculiar interest.

VI.—Contact Phenomena about the Borders of the Granite Batholiths.

About the borders of the various areas of granite and granite-gneiss, contact action is pronounced and often very striking. If the invaded rock be amphibolite, fragments torn from it are found scattered about in the gneiss, giving rise to inclusions presenting the various characters already described.

When the granite invades bodies of limestone, on the other hand, the phenomena resulting from the intrusion are more varied. The invading rock metamorphoses the limestone, and the products of alteration may be divided into three classes:—

(1) The alteration of the limestone into masses of granular, green pyroxene-rock, usually containing scapolite, or into a rock consisting of a fine-grained aggregate of scales of a dark brown mica.

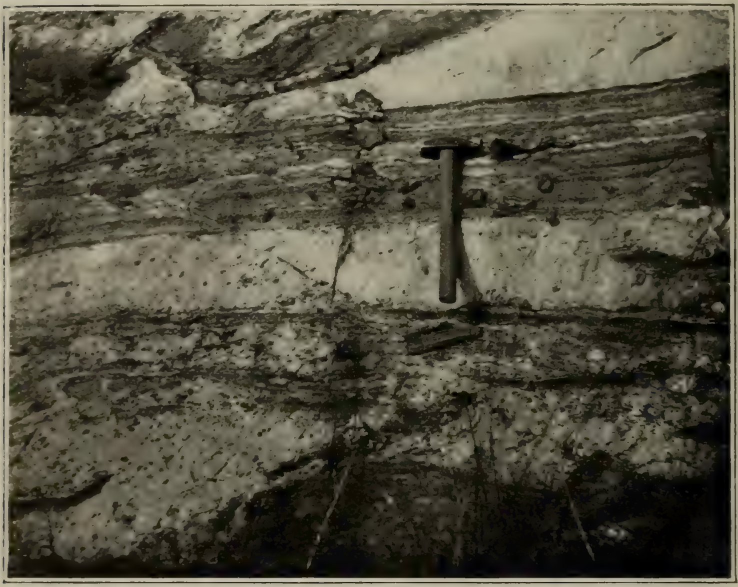
(2) Intense alteration of the limestone along the immediate contact, into a pyroxene-gneiss or amphibolite.

(3) In addition to these alteration products, in certain cases the granite dissolves or digests the invaded rock, having altered it in one or other of the manners above mentioned.

The alteration products of the first class may be considered as due to the heated waters or vapours given off by the cooling magma, that is, to be of pneumatolytic origin; while the alteration products of the second class result from the more immediate action of the molten magma itself. The products of these two classes of alteration have much in common, however, and naturally pass one into the other.

The evidence of the alterations of the second class, whereby the limestone is converted into amphibolite, is briefly as follows:—The sedimentary series, consisting chiefly of limestones interstratified with amphibolites, the former making up about one-half of the volume of the whole, is invaded by the granite batholiths, torn to pieces and scattered as fragments through the invading rock. These fragments are all composed of amphibolite, and none consisting of limestone can be found. The persistence of this phenomenon throughout the whole area suggests an alteration of limestone to amphibolite.

In certain places, especially about the border of the Glamorgan batholith, where the line of contact is especially well exposed for study, a gradual passage of the limestone into amphibolite can actually be observed, the former rock having gradually developed in it feldspars, hornblende and pyroxene in progressively greater amount, until it eventually becomes an amphibolite. A detailed description of this form of alteration, with a chemical and mineralogical



Limestone passing into pyroxene gneiss and amphibolite cut by granite. Southern border of Glamorgan batholith, Maxwell's Crossing.

study of the transitional rocks, will be found in the report on the geology of the Haliburton and Bancroft areas to which reference has already been made. (See also pp. 63-73 of this Guide Book.)

Evidences of alteration of the third class are less frequent and less striking. Nevertheless, in certain cases it appears to be practically certain that there has been a distinct solution of the invaded rocks by the granite. This,

however, probably took place on a comparatively small scale.

An occurrence of this kind is found on the southern extension of Kasshabog lake, in the township of Methuen. Here the banded amphibolite is invaded by the granite-gneiss, which has broken it into fragments and partly dissolved some of them, giving rise to a greyish, streaky-looking mass of irregular composition, much lighter in colour than the amphibolite and darker than the granite, being grey instead of reddish.

Other examples of the same phenomenon, but on a larger scale, may be seen at many places about the margin of the Anstruther batholith. At the northern end of this occurrence, where the granite-gneiss of the batholith runs up into the township of Monmouth, it is bounded on the north by an extension of what is known as the Catchecoma gneiss. This is a basic rock which resembles in appearance a light-coloured amphibolite. To the north of the Catchecoma gneiss is a dark amphibolite, and then a band of limestone. The granite-gneiss, elsewhere red, becomes grey in colour and poor in quartz as the northern boundary is approached, and passes into the Catchecoma gneiss, which is at first seen to hold a few tear-shaped inclusions of the amphibolite; these become increasingly numerous as the contact is approached where the amphibolite is reached, through which there run streaks of the invading rock. Evidently the amphibolite has been partly dissolved by the granite magma, and here the Catchecoma gneiss consists apparently of the granite magma rendered basic by the solution of amphibolite.

VII.—Distribution and Thickness of the Grenville Series.

In an area where the geological structure is so complicated, and where the strata must have been invaded by such immense bodies of igneous material, it is difficult to determine the true succession and thickness of the sedimentary series. The area is traversed by the Hastings road, which for a distance of 25·3 miles (40·7 km.) passes continuously across the limestones and amphibolites of the Grenville series, and throughout this whole distance crosses these rocks nearly at right angles to their strike.

Furthermore, throughout nearly the whole distance these strata dip in a southerly direction at high angles.

It must be noted, also, that along the whole length of this section a continuous alternation of beds of varying character is presented, and therefore it is not a foliation, but a true bedding that is observed. It is, furthermore, to be noted that, although this series may have been repeated by isoclinal folding, there is no stratigraphical evidence that such is the case, and this folding has nowhere brought up the basement upon which the series was deposited—a fact which indicates again that the series, even if so folded, is extremely thick.

It may be safely stated that the Grenville series presents by far the thickest development of Pre-Cambrian limestone in North America, and that it presents at the same time one of the thickest series of Pre-Cambrian sediments on that continent.

Not only has the Grenville series a great thickness, but it has a great superficial extent. It is exposed more or less continuously over an area of 83,000 square miles (208,000 sq. km.) in Eastern Canada and the State of New York. In areal extent, therefore, it can be compared in North America only with certain of the greatest developments of the Palæozoic limestones, as, for instance, the Knox dolomites of the southern Appalachians. In all probability, its original areal distribution was considerably greater than above stated, although this cannot be definitely determined on account of the great erosion to which the Laurentian protaxis has been subjected.

It may here be mentioned that the 'Hastings series,' a designation given by Logan to certain rocks of the Madoc district, has proved, as Logan conjectured might be the case, to have no independent existence, but to be merely the less metamorphosed portion of the Grenville series seen in the southern part of the Bancroft area. It is, however, practically certain that in this Madoc district the comparatively unaltered rocks, which were designated by Logan as the Hastings series, really consist of two unconformable series; and it is possible also that in the Grenville series, as shown upon the Bancroft sheet, there may be two formations separated by an unconformity, as suggested by the occurrence of certain conglomerates. If, however, there are proved to be two formations within this area, these are identical in petrographical character,

and are so intimately infolded and so highly metamorphosed that their respective distribution in the Bancroft area cannot now be determined.

VIII.—Relation of the Grenville Series to other Pre-Cambrian Series.

In the southern portion of the Laurentian highlands to the west of the area occupied by the Grenville series, that is, north of Lake Huron and in the district about Lake Superior, Rainy lake and Lake of the Woods, other Pre-Cambrian series, differing essentially in petrographical character from the Grenville series, are found. These are, enumerated in ascending order, the Keewatin, Huronian, and Keweenawan series. Up to the present time the Grenville series has nowhere been found in contact with these; but it is hoped that the relation of these eastern and western Pre-Cambrian developments may eventually be determined, in order that a correlation may be made between them. Until this has been done, however, their relations must remain a matter of mere conjecture. The two successions, then, are as follows:—

Western District.

Upper Cambrian—Potsdam sandstone		
		–Unconformity–
Pre-Cambrian	Keweenawan.	
	–Unconformity–	
	Huronian	Upper (Animikie).
		–Unconformity
		Middle.
		–Unconformity
		Lower.
	–Unconformity–	
	Keewatin.	
	Intrusive contact.	
Laurentian.		

Eastern District.

Upper Cambrian—Potsdam sandstone.	
–Unconformity–	
Pre-Cambrian	Grenville series. *Intrusive contact.*
Laurentian.	

It will be noticed that here the term Laurentian is used in a somewhat different sense from that in which it was employed by Logan. In Logan's original classification of the Laurentian this term—apart from the Upper Laurentian, which was proved to be composed essentially of anorthosite intrusions—included two series differing in character, namely, the Lower Orthoclase (Fundamental') gneiss and the Grenville series. Now that investigations have shown that these two series differ in origin (one being essentially a great development of very ancient sediments, and the other consisting of great bodies of igneous rock underlying and intruded through them), it becomes necessary to separate these two developments in drawing up a scheme of classification. As the lower gneisses, forming what has been termed the 'Fundamental gneiss,' have an enormously greater areal development than the overlying sedimentary series, constituting as they do a very large part of the whole Northern Protaxis, and forming the basis upon which the Grenville series rests, it has been proposed that the term Laurentian be restricted to this great development of igneous gneisses [**5**, p. 89 and **6**, p. 191.

The Grenville series is thus separated from the Laurentian system, and the name is employed to designate the sedimentary series which overlies the lower gneisses and granites. The name Laurentian will, in addition to its geological use, continue to have a geographical or physiographical significance, as, for instance, in the term Laurentian Protaxis, which latter forms so striking a feature of the continent of North America, and is underlain chiefly by the gneisses of the Laurentian system.

In its petrographical character and in the display of the products of metamorphism which it presents, this great area on the southern border of the Canadian protaxis resembles in many respects certain classic localities of the 'Grundgebirge' on the continent of Europe [**10**], but in none of them, with the possible exception of the Scandinavian peninsula, can the successive stages of metamorphism be so clearly traced, or its final products be studied in such enormous development. The area is very instructive, as presenting a section of the *appareils granitiques*, the 'roots of the mountains,' laid bare for study by the processes of denundation.

The Laurentian protaxis from early times has been relatively an area of progressive uplift; while that of the

great plains to the south has been an area of progressive sinking, since upon it has been deposited in successive stages a series of great systems of sedimentary rocks.

Here along the border of these two great geological units, the deep erosion reveals, it would seem, the mechanism of elevation, the granite magma rising from the depths and in all probability passing out from beneath the subsiding area to the south, lifting the old Laurentian highlands as the liquid in the Bramah press lifts the ram when the piston sinks.

IX.—Summary.

(1) The Laurentian system of Sir William Logan in Eastern Canada consists of a very ancient series of sedimentary strata—largely limestones—invaded by enormous volumes of granite in the form of batholiths, representing what Logan termed the Fundamental gneiss.

(2) This sedimentary series is one of the most important developments of Pre-Cambrian rocks in North America, and presents the greatest body of Pre-Cambrian limestones on that continent.

(3) This great Pre-Cambrian limestone series is best designated as the Grenville series.

(4) The invading batholiths of granite are of enormous extent. They possess a more or less distinct gneissic structure, due to the movement of the magma, which developed a fluidal and, in the later stages of intrusion, a protoclastic structure in the rock.

(5) The granite-gneiss of the batholiths not only arched up the invaded strata into a series of domes, but 'stoped' out portions of the sides and lower surface of the arches, the fragments torn off from the walls and roof by the invading granite being found scattered throughout the mass of the invading rock. This 'stoping' [**4,** p. 269], however, probably developed only a small part of the space which the granite now occupies.

This structure is thus identical with that found by Dr. Lawson in the Keewatin area of the Lake of the Woods district, west of Lake Superior, and by Adams in the district north of the

Island of Montreal. It is a structure which probably persists throughout the whole northern protaxis of the continent [**2**].

(6) The invading granite not only exerted a mechanical action upon the invaded strata, but also by its action upon these latter gave rise to a variety of metamorphic products, among which one of the most important is amphibolite produced by its action upon the limestone.

(7) The nepheline syenite is a peripheral phase of the granite intrusions, and is developed chiefly along the contact of the granite with the limestone. The nepheline syenite magma frequently contained a large excess of alumina which, upon the cooling of the rock, separated out as corundum, giving rise to corundum syenites, which are extensively worked for this mineral.

(8) The invading batholiths and allied intrusions of granite appear to occupy the greater part of the great northern protaxis of Canada, which has an area of approximately 2,000,000 square miles (5,000,000 sq. km.) It has therefore been considered advisable to restrict the name Laurentian to this great development of the Fundamental gneiss, which, although intrusive into the Grenville series, nevertheless underlies and supports it.

(9) The relation of the Grenville series, forming the base of the geological column in Eastern Canada, to the Huronian and Keewatin series, which are the oldest stratified rocks in the western part of the protaxis, has yet to be determined, the two not having so far been found in contact; nowhere, moreover, either east or west, has the original basement upon which the first sediments were laid down been discovered. These are everywhere torn to pieces by the granite intrusions of the Laurentian.

ITINERARY OF THE EXCURSION.

ANNOTATED GUIDE.—(Montreal to Ormsby Junction.)

Miles and Kilometres.

0 m. 0 km. **Montreal** (Bonaventure station, Grand Trunk railway), with a population of 592,000, is the largest city and the commercial metropolis of Canada. It is situated on the south side of an island of the same name at the confluence of the Ottawa and St. Lawrence rivers. It is at the head of ocean navigation and at the commencement of lake and river navigation. The city has been built about the base of Mount Royal, an intrusive mass of Devonian or post-Devonian age, composed principally of essexite and nepheline syenite, which rises to a height of 763 feet (232·56 m.) above the sea or 742 feet (226·16 m.) above the standard low water of the river. On its sides may be seen terraces and beaches, the records of post-glacial subsidence, the highest shore line having an altitude of 568 feet (173·1 m.) above the sea. St. Catherine and Sherbrooke streets respectively follow two of the most important terraces. The city is underlain by rocks of the Trenton group, which furnish the grey limestone so much in use locally for building purposes. Utica shale outcrops at Verdun and Point St. Charles and underlies the harbour and the south end of St. Helen's island. Masses of limestone included in the igneous breccia of St. Helen's island are of Lower Helderberg (Upper Silurian) and Oriskany (Lower Devonian) ages. These occurrences are of interest as evidences of the extension of the Upper Silurian and Lower Devonian seas as far inland as Montreal. The Trenton is usually credited with a thickness of 600 feet (183 m.) and the Utica 300 feet (92 m.) in the region surrounding Montreal.

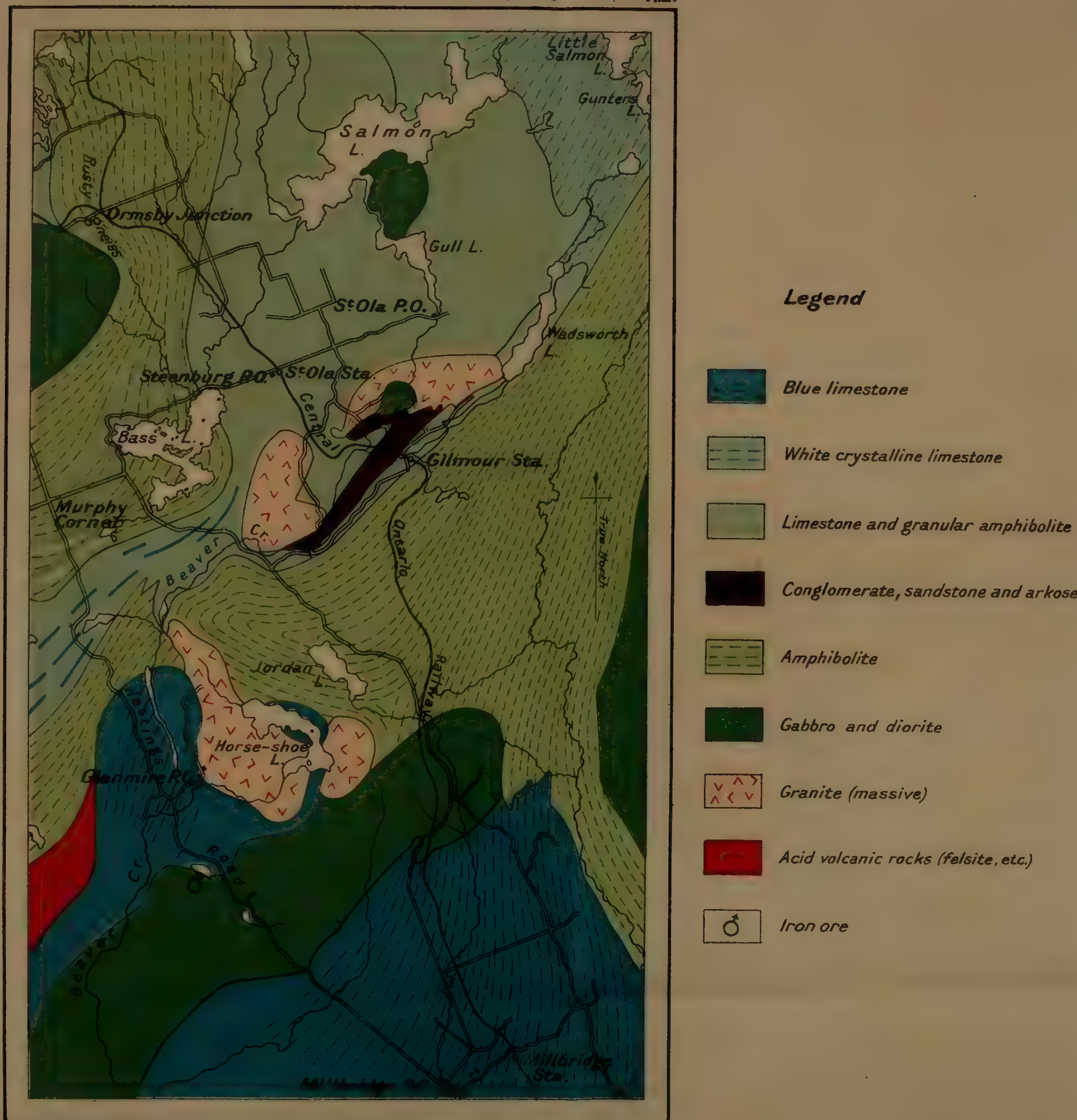
Leaving Montreal the railway runs to the southwest following a natural depression, which extends nearly to the shores of Lake St. Louis,

an expansion of the St. Lawrence river. Between Lachine and Ste. Anne de Bellevue, the railway passes through a beautiful and highly cultivated stretch of country, sloping gently to Lake St. Louis. The great expanse of comparatively low flat land which borders the St. Lawrence river from Montreal to Trenton is underlain by the almost horizontal strata of Upper Cambrian (Potsdam formation) and Ordovician ages (Chazy, Calciferous, Black River and Trenton formations) with the exception of the region between Brockville and Kingston where this succession is interrupted by granitoid gneisses and quartzites of Archean or Pre-Cambrian age. Throughout the greater part of this area, the underlying rock formations are concealed by a heavy mantle of marine sands and clays of Champlain age. This great drift-covered Palaeozoic plain with its eminently flat surface presents a strong contrast to the uneven topography of the Archean rocky plateau. The average elevation of this plain in the vicinity of Montreal is about 100 feet (30·5 m.), gradually rising westward until in the vicinity of Central Ontario Junction, it is almost 600 (183· m.) feet above the sea.

232·85m. **Trenton.**—(Grand Trunk Railway station).
375·0 km. Alt. 280 ft. (85·3 m.) At Trenton the train is switched from the Grand Trunk railway to the Central Ontario railway, now being operated by the Canadian Northern railway.

Trenton.—(Central Ontario Railway station) Alt. 258 ft. (78·6 m.).

257·86 m. **Canadian Pacific Railway Junction.**—
415·0 km. Alt. 598 ft. (182·3 m.) From the junction with the Canadian Pacific railway, known also as Central Ontario Junction, the railway runs north. The main mass of Archean or Pre-Cambrian rock is not reached until Bannockburn station is approached. The transgression of the Palaeozoic sea along this portion of the great protaxis began early in Ordovician time. This marine invasion was inaugurated by the shallow water conditions resulting in the deposition of



Geological Survey, Canada

Route map, **Hastings Road**

Miles
1 0 5

Kilometres
1 0 5

certain conglomerates, grits and sandstones which mark the base of the Lowville (Birdseye) and Black River formations.

Owing to inequalities of the pre-existing land surface as well as to subsequent unequal erosion, the present line of contact between the Palaeozoic and the Archean is very intricate. As a consequence large irregular-shaped masses of flat-lying Palaeozoic strata extend for many miles beyond the general direction of the line of junction, while corresponding insets of highly inclined Archean rocks break up the continuity of the main mass of the Palaeozoic rocks. This irregularity in the line of division between these two series of formations is further accentuated by the occurrence of outliers of flat-lying Palaeozoic rocks, some of which are now separaated by intervals of many miles from the main mass to the south.

263·34 m. **Marmora.**—Alt. 594 ft. (181 m.)
423·8 km.

282·92 m. **Millbridge.**—Alt. 944 ft. (287·7 m.)
455·3 km. The party will leave the railway at Millbridge, and will drive up the Hastings road to Murphy's Corners and thence to St. Ola station.

Between Millbridge station and Millbridge post office, the blue limestone of the Grenville-Hastings series is excellently exposed. It is well-bedded, heavier beds alternating with thin beds which are usually laminated. Some of these beds are more distinctly blue in colour and effervesce readily when a drop of diluted acid is placed on the surface of the rock; others are greyer in colour and give a distinct effervescence only when powdered. The lamination undoubtedly represents the original bedding of the rock, and while the rock in many places is much contorted, the limestone still retains its blue colour, showing that the alteration has not been nearly so intense as in the case of the same series further north, where metamorphism has entirely dissipated the colour of the limestones, producing at the same time a certain coarsening in grain.

A qualitative chemical examination shows that the blue beds are limestones, all more or less impure, and that the grey beds are much more impure varieties of the same rock. The proportion of magnesia present does not seem in any case sufficient to constitute a dolomite, although in the absence of a quantitative examination the actual proportion of this base present remains uncertain.

A microscopic examination of a series of thin sections of specimens of the various varieties of the rock, shows that all stages of the continuous transition from a limestone containing only a few flakes of brown mica to a micaceous paragneiss (pflastergneiss) are represented. The latter constitutes the hardest grey beds and holds scarcely any calcite, but contains, on the other hand, much biotite, in the form of individuals, which usually possess a somewhat frayed outline and lie in a fine-grained base of colourless untwinned grains, some of which are quartz, but some, and perhaps the majority, are probably orthoclase. Pyrrhotite also occcurs scattered through the rock, but no trace of any magnesia constituent, except the biotite, was found in any of the slides, nor was any mica but biotite present. In most of the sections minute rutile crystals, identical with those so commnoly found in clay slate, were found.

The occurrence evidently represents a great body of calcareous sediments, made up of an alternation of beds which vary greatly in the amount of impurity (silt or mud) which they contain, and which, under the relatively slight metamorphism which this portion of the area has undergone, has suffered a diagenetic alteration into the varieties of limestone and paragneiss above described. In the movements to which the strata have been subjected, the purer limestone beds, curiously enough, are seen to have been less resistant than the more impure gneissic beds, for they can be seen on the weathered surface to have been torn apart, while the gneissic beds flow in between the

separated fragments. A considerable amount of local solution and redeposition has also taken place, as shown by the presence of a coarse-grained development of the gneissic bands along certain irregular lines often running transverse to the bedding.

This area of blue limestone, with its pure and impure bands, under a more intense metamorphism, such as that to which the more northerly portion of the district has been subjected, would develop into a series of coarsely crystalline white limestones, with interstratified bands of the rusty biotite-bearing gneisses, which are so extensively exposed elsewhere in the district, and which are so commonly found in all developments of the Grenville series in Canada. Such an occurrence as this, therefore, represents the Grenville series, in a less altered form.

284·29 m. 457·5 km. **Millbridge Corners** is between lots 20 and 21, Hastings road. Before the building of the railway this road was one of the main highways of communication, but is now little used, except for local purposes. It crosses the strike of the rocks nearly at right angles, however, and thus affords a good cross section.

At the "Corners" the bluish limestone is much contorted and nearly vertical in attitude. Very narrow, lenticular bands of white calcite are being developed as a result of recrystallization.

285·54 m. 459·5 km. From lot 25 to lot 33 the road passes through a swampy tract with exposures of similar limestones at intervals. The beds, which are nearly vertical, dip sometimes to the south, but usually in a northerly direction. In places veins of quartz together with some dolomite, intersect the limestone. On lot 32 the limestone is lighter in colour, owing to more advanced metamorphism. Between lots 33 and 36 the limestones are inclined at a very high angle to the south.

This limestone succession is interrupted on lot 40 by an intrusion of diorite. The limestone

at the contact is altered into a fine-grained aggregate of very pale green pyroxene and plagioclase, but a large included block of the limestone-paragneiss series, intensely metamorphosed, has been caught up by the igneous mass. The narrow defile occupied by the road near the summit of the hill has for a long time been
287·79 m. known as the "Hole in the Wall."

463·2 km. This diorite (about lot 48) is composed essentially of hornblende and plagioclase with a little accessory iron ore and an occasional grain of pyrite. The hornblende is pale green in colour and somewhat fibrous in character, its appearance suggesting its derivation from pyroxene, although no trace of pyroxene now remains. The plagioclase has undergone considerable saussuritization, the resulting products being mainly zoisite and epidote. It is probably the rock referred to by Vennor in his report on the geology of the district as "blotched diorite."

The diorite from lot 49 is rather finer in grain and more basic, the hornblende in well defined individuals being much more abundant than the plagioclase. Thin sections show the rock to be made up essentially of hornblende and plagioclase. It is much more altered than the "Hole in the Wall" diorite and some of the hornblende is undoubtedly secondary.

290·79 m. This diorite on lots 56 and 57 to the west of
468 k.m. the road and close to the township boundary differentiates into a large body of titaniferous magnetite opened up and worked at the Orton mine. This mine is the property of the Tivani Electric Steel Co. of Belleville, Ont. Two analyses show the ore to have the following composition:

Iron................	51·45	60·84
Sulphur.............	trace........	
Titanium............	7·50	7·50
Nickel..............	0·112........	
Vanadium...........	trace	0·11

This ore has been used very successfully for the manufacture of tool steel in the electric furnace by the Evans-Stansfield process [**12**, p. 52].

290·79 m. On lot 56 the limestone series is again seen
468 km. with an almost vertical attitude although both northerly and southerly dips at high angles are seen in the exposures. At one place a small mass of gabbro, probably an apophysis of the main mass to the south, is intruded into the sedimentary rocks.

292·03 m. About lot 62 a mass of pyrrhotite about 30
470 km. feet (9·1 m.) in width is interstratified with blue limestome and lighter coloured dolomite, the whole series dipping to the south at a high angle.

294·47 m. From lot 80 to lot 86 a fine-grained and
473·9 km. evenly foliated amphibolite occurs. From this point to Murphy's Corners the limestones and amphibolites are interstratified with one another, dipping to the south at a high angle. Owing to progressive metamorphism and consequent recrystallization, the limestone has lost much of its bluish-grey colour and some bands are quite white.

The fine-grained amphibolites and gneisses which are interstratified with limestones represent either intercalations of muddy sediments analogous to those forming the paragneisses in the vicinity of Millbridge, or have originated from the complete alteration of volcanic ashes which fell into the sea during the deposition of the limestones. Their chemical composition affords very little distinctive information as to their genesis, but their association with intrusions of gabbro, possibly truncated volcanic centres, suggests a volcanic origin.

298·22 m. **Murphy's Corners.**
479·9 km. From Murphy's Corner's the road follows the town line between Limerick and Tudor until it reaches Bass lake. Thence it passes to the west and north of this lake and joins the railway at St. Ola station (Steenburg P.O.) In this interval limestones, amphibolites and rusty-weathering paragneisses interstratified with one another are exposed. The limestone is apparently relatively unimportant, but this

is probably due to the fact that this rock, being softer and more readily eroded than the amphibolite, usually occupies depressions and is thus very frequently largely drift covered.

303·52 m. **St. Ola Station.**—Alt. 1068 ft. (325·5 m.)
488·4 km. At St. Ola the party will again take the train and proceed to Ormsby Junction.

307·32 m. **Ormsby Junction.**—Alt. 1,160 ft. (353·6 m.)
494·6 km.

Geology in the Vicinity of Ormsby Junction.

At this place there are large exposures of the typical "rusty gneiss" (paragneiss) which is so commonly associated with the crystalline limestones of the Grenville series. In the vicinity of mile post 97 to the west of the station, there are several rock-cuts blasted out to secure the required grade for the railway. This band of gneiss is approximately a mile wide. The gneiss is light grey to very dark grey on a fresh fracture, but weathers with an intensely rusty surface. A typical specimen of the rock, taken from a cutting on the railway track half a mile west of Ormsby Junction, when examined under the microssope, was found to be very fine and uniform in grain and to possess a distinct foliation. It shows a colourless allotriomorphic base, consisting chiefly of quartz and feldspar, through which are distributed a great number of little flakes of biotite, separate from one another, but all with a marked parallel alignment. The biotite is strongly pleochroic in deep brown and pale yellow colours. The feldspar, which is clear and colourless, shows no twinning. Some of the quartz grains are nearly round and have an appearance strongly suggestive of sand grains. In addition to these minerals there is present as an accessory constituent a small amount of garnet, in individuals having a well-marked polygonal outline, showing that the mineral has a good crystalline form. It is quite isotropic in character. There are also a few little rounded grains of zircon or sphene, as well as a small amount of hydrated oxide of iron, occurring as minute grains, whose form suggests their derivation either from a rhombic pyroxene such as occasionally occurs in rocks of this class, or possibly from pyrite. No pyrite, however, occurs in the sections, neither are there any carbonates present.

Other specimens from a cutting on the railway one hundred yards west of Ormsby Junction are similiar in character to the rock just described. Microsocopic examination, however, shows that while less biotite is present, the rock contains a large amount of a yellow sulphide of iron, apparently pyrrhotite. Quartz and orthoclase are the most abundant constituents in this rock, which also contains a few grains of muscovite and zircon, the former mineral occurring in occasional large individual skeleton crystals. The grains of the yellow sulphide have an irregular outline, or are present in the form of little strings running parallel to the foliation of the rock. When examined by reflected light, nearly every grain of this sulphide is seen to have intimately associated with it a black mineral with a metallic lustre, which is evidently magnetite. This latter mineral usually forms a border around the yellow sulphide, wholly or partially enclosing it. These metallic minerals occur not only in larger grains, but also as a fine dust scattered throughout the rock.

At one place by the side of the road bed a band of this gneiss has been opened up by a small pit, being mistaken for an iron ore. This variety of the rock is black in colour on a fresh fracture, and when examined under the microscope is seen to be composed chiefly of quartz, hornblende and magnetite. The hornblende is arranged in rudely parallel lines, giving the rock a distinct foliation. It is deep green in colour, and distinctly pleochroic in greenish and yellow tints. The magnetite has a black metallic lustre, and frequently possesses a good crystalline form. An immense number of very minute garnet crystals occur through the rock, resembling those in the rusty gneiss above described, but very much more abundant. Although so small, they are rather uniformly distributed, occurring not only in the hornblende and quartz, but also in the magnetite. They are isotropic and possess a good crystalline form.

This band of gneiss suggests in its appearance in the field certain belts of the magnetite-grünerite schist in the iron ranges on the south side of Lake Superior. The microscopic examination of the rocks, however, shows them to be quite different from the schist in question, biotite being the only iron-magnesia constituent present, except in the case of the narrow band above referred to as having

been mistaken for an iron ore, which contains hornblende. Carbonates are also absent, except in traces, and the iron is thus present almost exclusively in the form of a disseminated sulphide, the rocks belonging to the ordinary rusty weathering paragneisses so extensively distributed throughout the sedimentary portion of the area.

ANNOTATED GUIDE—continued.

308·8 m. 497 km. **Brinklow.**

315·5 m. 507·7 km. **Turriff.** Alt.: 1,098 ft. (334·6m.)

319·76 m. 514·6 km. **L'Amable** Alt.: 1,073 ft. (327 m.).

The railway here runs through an old "brûle," with heavy rock cuttings in white crystalline limestone. The valleys between the rocky ridges are occupied by extensive deposits of sand and gravel. In the vicinity of L'Amable station "feather" amphibolite (see page 24) is seen interstratified with thinly-bedded crystalline limestones.

323·09 m. 518·9 km. **Bronson.** Alt. 1,077 ft. (328·2 m.). The first rock cut to the east of this station is in a typical crystalline limestone of the Grenville series. It is distinctly bedded and remarkably free from impurities. Some of the beds still retain some of their originally bluish-grey colour. The action of the weather is very characteristically shown in this exposure. Autoclastic action is illustrated in the dislocation of certain dykes of pegmatite intrusive with the limestone, the limestone very evidently being much more plastic than the pegmatitic material.

A short distance west of Bronson station the railway siding employed by the Ontario Marble Quarries, Limited, is reached. These quarries, which are situated on lots 29 and 30, con. X of the township of Dungannon, and lots 41 and 42 of the Hastings road, Township of Faraday, yield a great variety of ornamental marbles, including breccias of veined, streaked and

clouded types of singular beauty. These are produced by differential movements accompanied by more or less intense metamorphism induced in beds of limestone and dolomite of varying degrees of purity. Among the more important varieties may be mentioned the following:

(1) "*Bancroft Cipollino*," so called from its resemblance to the Italian Cipollino, is a green and white variety.

(2) "*Laurentian Vein*," This consists of broken and faulted bands of magnesian limestone, drab and cream in colour, cemented together by a relatively small amount of dark matrix, which consists of magnesian limestone with much biotite and a smaller amount of a nearly colourless hornblende. This variety passes into a breccia with a dark base and fragments of lighter colour.

(3) "*Laurentian Blue*." A fine-grained bluish grey marble in which the original bluish colouring matter has not yet been entirely destroyed by metamorphism.

(4) "*Rose Fantasia*." A marble irregularly banded or streaked, presenting a great variety of colours, often of great brilliancy. The colours represented are white, pale pink, bright red, and cream colour.

(5) "*Bancroft Green*." This is a fine-grained light green rock composed chiefly of a very pale green hornblende with some calcite. The variety called "serpentine" is almost identical in character, the hornblende, however, being more fibrous (actinolite), while in addition pale brown biotite is present.

A white granular marble (dolomite) also occurs near the railway station at Bronson.

The company has installed a complete plant for quarrying and sawing these marbles.

Three small fine-grained black dykes of malchite cut the marble in one part of the quarry. These are composed essentially of a dark green hornblende and plagioclase. These minerals are allotriomorphic in form, although the plagio-

clase has a tendency to assume a lath-like development. The rock also contains a considerable amount of scapolite as an accessory constituent. A small quantity of a black iron ore in rude, more or less rod-like forms, and a few grains of pyrite are also present. The rock is very fresh.

After having inspected these quarries the party will return to the train and continue the journey to Bancroft.

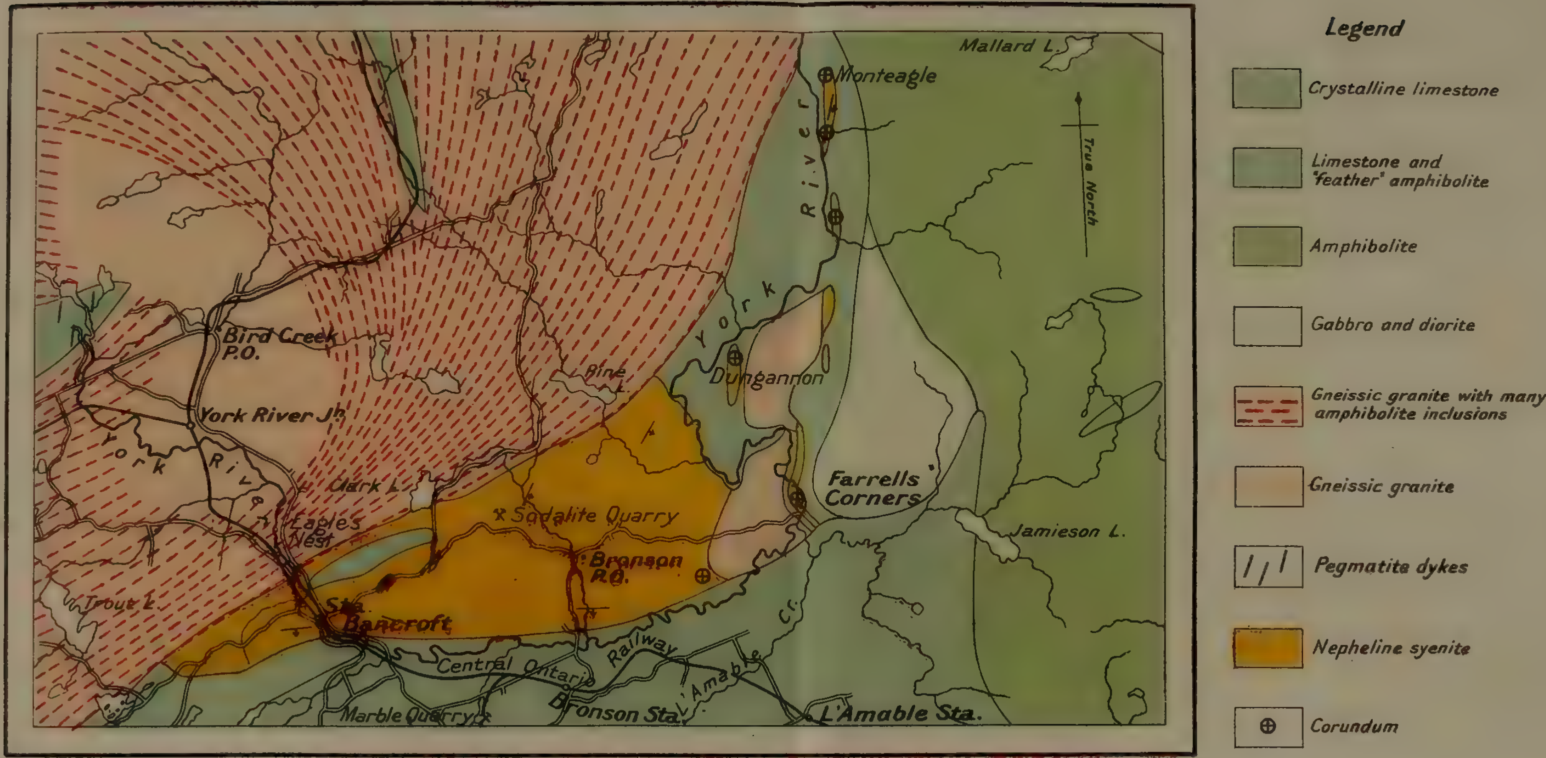
Geology in the Vicinity of Bancroft.

The Grenville series, which with its associated intrusive masses of diorite and gabbro is traversed by the Hastings road in a direction almost at right angles to the strike of these rocks, furnishes abundant evidence of progressive metamorphism. At Bancroft, however, the continuity of this important series of very ancient crystalline sedimentaries is interrupted by the intrusion of the great northern granite batholith, flanked to the south by a wide border of nepheline and other alkaline syenites. Small and isolated inclusions of the Grenville series occur scattered through the batholith to the north, linearly arranged when they occur in the direction of the movement of its flow, as shown by their relation to the direction of its foliation. These are clearly fragments of the limestone cover of the batholith which have been folded, or have fallen down, into the magma of the invading batholith.

The nepheline syenite shows a distinct banding and foliation, conforming in strike to the foliation of the gneissic-granite, as well as to the bedding of the limestone series.

At Bancroft this nephleine syenite is nearly a mile (1·6 km.) in width measured across the strike of the foliation, the dip being to the south. East of the village it increases ı .pidly in volume, attaining its maximum development in the vicinity of Bronson post office, where extended and often almost continuous outcrops may be found for over two and a half miles (4 km.) in a north and south direction. In this, which may be termed the Bancroft district, the nepheline and associated alkaline syenites cover an area of about 15 square miles (37 sq. km.).

A2.



Geological Survey, Canada.

Bancroft and Vicinity

Miles

1 0 5

Kilometres

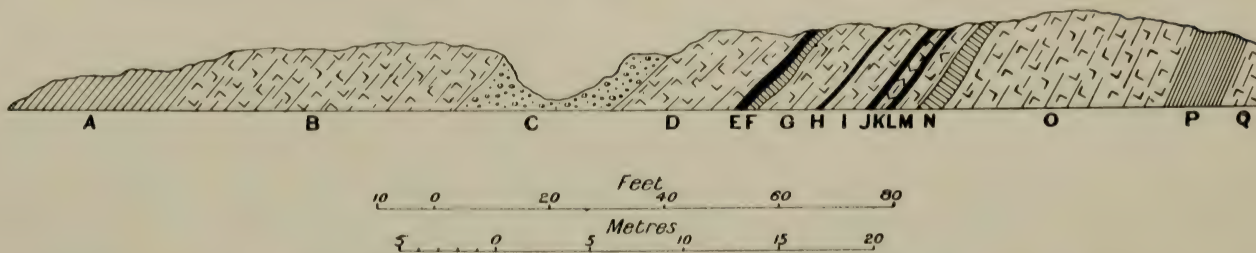
1 0 5

These syenites show a marked variation in the relative proportion of the principal mineral constituents. Indeed extreme and rapid variation in composition is one of the most noteworthy features of their development, so that it is possible to obtain from the same exposure, and even from contiguous bands, different and quite distinct types of rock.

Some varieties are abnormally rich in nepheline, while others contain a much smaller proportion of this mineral, passing by insensible gradation into alkaline-syenites, composed almost wholly of feldspar. Certain types are relatively rich in ferromagnesian constituents, which may be either mica or hornblende, while other phases of these rocks contain very little, if any, of these coloured minerals. Some exposures are characterized by the interesting alkali-hornblende to which the name hastingsite has been given, while in some localities garnet is present in considerable amount. The actual relation of these syenitic occurrences to the granite batholith is not observable along this line of section, since the actual contact between the two cannot here be seen, but examination elsewhere throughout the region has led to the conclusion that the nepheline and associated alkaline syenites represent a peripheral differentiation phase of the invading soda-rich granite along its contact with the limestone. The actual relations of the nepheline syenite to the Grenville series, on the other hand, is well illustrated in the railway cutting in the village of Bancroft, which exposes the line of contact. The character of this junction is shown in the accompanying section through this rock cut at Bancroft.

The nepheline syenite, which is clearly the invading rock, seems to permeate the limestone, the latter being in process of replacement by the syenitic magma. The masses of limestone caught up in the syenite become gradually disintegrated in the magma until they survive merely as separated, irregularly rounded grains of calcite often enclosed in the individuals of perfectly fresh nepheline, hornblende or other minerals of the nepheline syenite or lying between these with the form of the latter impressed upon them. The derivation of these isolated grains of calcite from the neighboring limestone is quite evident even under the microscope for they sometimes show the deformation and strain shadows observable in the invaded limestone, while the minerals of the nepheline syenite in

Section in cutting on Central Ontario railway at Bancroft, showing contact of limestone and nepheline syenite.



A. White crystalline limestone with rusty weathering gneiss.
B. Foliated syenite with segregations of black mica.
C. Sand and gravel (Drift covered).
D. Well foliated nepheline syenite; contains a little calcite.
E. Coarsely crystalline limestone with black mica.
F. Nepheline syenite with much calcite and black mica.
G. Well foliated nepheline syenite with black mica and a little calcite.
H. Coarsely crystalline limestone with black mica.
I. Well banded nepheline syenite, some bands nearly pure nepheline and feldspar. Contains a little calcite.
J. Calcite and black mica.
K. Nepheline syenite with a little calcite.
L. Very impure limestone with black mica.
M. Dark nepheline syenite, well foliated, some calcit cut by dyke of syenite.
N. Very coarse grained nepheline syenite pegmatite, containing sodalite, black mica, apatite, calcite.
O. Nepheline syenite, basic, contains much calcite chiefly as thin beds.
P. Rusty gneiss.
Q. Nepheline syenite with dark "schlieren". Contains much calcite.

which they are imbedded are absolutely free from all signs of pressure.

The banding and foliation of the nepheline syenite gradually passes over into the bedding and foliation of the limestones. Abundant development of black mica in the limestone at the immediate contact with the nepheline syenite is seen here as in many other places in the district where the contact of these two rocks can be examined. Thin beds of limestone and associated paragneisses and amphibolites included in the syenite are sometimes so filled with the minerals characteristic of the syenite that it is almost impossible in the field to determine whether they belong to the limestone series or to the invading magma. North from Bancroft on the Hastings road, exposures of nepheline syenite with some included bands of limestone are seen on the east side of the road.

One mile from the village the gneissic granite of the great northern batholith is reached, forming a great cliff known as the "Eagle's Nest". The granite-gneiss here is reddish and possesses a distinct foliation, striking almost at right angles to the road and dipping south, thus disappearing beneath the nepheline syenite border complex, which in its turn is overlaid by limestone. This gneissic granite is of medium grain with occasional coarsely crystalline segregations. Under the microscope it is seen to be composed of orthoclase, microcline, albite and quartz. Only a very small quantity of biotite is present. A ferriferous variety of sphene, magnetite and occasional small crystals of ziron complete the list of constituents. The rock shows marked evidence of pressure. This is especially seen in the quartz, which always displays strain shadows and is frequently granulated along certain lines.

It is a typical representative of the granite gneiss of the northern batholith of this area ("Fundamental Gneiss") except that here it is practically free from the dark amphibolite inclusions which are such a characteristic feature of the gneiss in almost every other part of the region.

About three miles (4·8 km.) north-east of Bancroft, the nepheline syenite is in certain places very rich in sodalite, this mineral being especially abundant in very coarse-grained pegmatite segregations which usually occur interbanded with the normal type of nepheline syenite. The colour of the sodalite varies from a very dark cobalt blue

to a much paler tint, but fades somewhat on exposure to the weather. The mineral is susceptible of a high polish and is eminently suitable for interior decorative work. The prsence of irregular veins of bright red natrolite (spreustein) with clear colourless orthoclase serves to increase its ornamental value. The occurrence of sodalite found on lot 25, con. XIV of the Township of Dungannon, has been quarried in an opening 250 feet (76·2 m.) long and from 40 to 50 feet (12 to 15 m.) in width. A shipment of 130 tons of sodalite was made from this quarry (Princess Quarries) in 1906, some of the blocks secured weighing several tons. These were sawed into suitable slabs and used for the most part in the decoration of the residence of Sir Ernest Cassell in Park Lane, Hyde Park, London.

ANNOTATED GUIDE.—Continued.

Miles and Kilometres.

318·77 m. 513 km. **Bancroft.**—Alt. 1073 ft. (327 m.)—The excursion follows the Central Ontario railway over a comparatively level sand and gravel flat, showing very plainly the devastations of an old forest fire, and then passes on to the line of the Irondale, Bancroft & Ottawa railway, also operated by the Canadian Northern railway, to York River Junction.

321·57 m. 518·5 km. **York River Junction.** Alt., 1,108 ft.(337·7 m.). Beyond this station the same level land continues, but rounded hills, often with precipitous slopes, composed of the granite gneiss of the Laurentian batholith, are seen at no great distance from the railway. A stretch of "drowned land," caused by the damming of York river, is then passed. The railway then crosses a portion of the granite batholith and reaches a comparatively narrow selvage of the limestone series in the vicinity of Baptiste lake, which is again flanked to the north by more granite belonging to the same intrusion.

327·57 m. 528·1 km. **Baptiste Lake.** Alt., 1,215 ft. (370·3 m.)—For about one and a half miles (2·4 km.) west of this station, the railway follows very closely the line of junction between the Grenville series

and the granite batholith to the south. The various cuttings show very typical sections of the crystalline limestones and interstratified, rusty-weathering paragneisses. The beds are twisted and contorted often into most fantastic shapes, at the same time being intruded by granitic apophyses, evidently emanating from the batholith, which occurs in close proximity. The limestone is usually very impure, owing mainly to the development in it of various silicates. In many places typical autoclastic structure has been developed by the dislocation of the more brittle gneissic bands, the separated fragments having been carried away from one another in the flowing limestone, which accommodated itself much more readily to the processes of stretching and compression. The series becomes more "granitized" on going toward the west, and, as a consequence, the limestone is in part replaced by a characteristic pale greenish pyroxene-gneiss. There are also coarsely crystalline pegmatite veins composed of red or pink feldspar, black mica and calcite.

333·27 m. 536·3 km. **Highland Grove** (formerly Deer Lake station). Alt., 1,233 ft. (375·8 m.)..

337·57 m. 543·2 km. **Mumford.** Alt., 1,259 ft. (383·7 m.)—A nepheline-bearing rock, which has been exposed in the railway cutting immediately west of the saw-mill at Mumford, forms part of a narow band which here lies on the contact of an almost pure white crystalline limestone with the granite of the Cardiff batholith. The limestone underlies the wooded area to the north of the railway, while the contact of the nepheline rock with the granite to the south is concealed by drift. A large included mass of this limestone, however, occurs by the side of the railway to the west of the nepheline rock to which reference has just been made. This nepheline-bearing rock shows a rapid and marked differentiation from place to place. One variety is composed almost entirely of salic constituents (chiefly nepheline), while the dark coloured phases consist almost entirely of the ferromagnesian minerals. A

thin section of one of these darker coloured varieties shows the rock to be a hornblende ijolite composed essentially of nepheline and a deep green hornblende. Oligoclase and sphene are very subordinate accessory constituents. In addition to these constituents, a considerable amount of calcite in large allotriomorphic individuals is also present, which is identical in character and mode of occurrence with that so commonly found in the nepheline rocks of this region. This calcite is especially abundant in a large exposure of the rock 25 paces west of the siding to the saw mill already mentioned. Another variety has a pseudoporphyritic structure, due to the development of larger, somewhat irregularly shaped individuals of nepheline through a fine-grained, almost black matrix, composed of deep green pyroxene and brown garnet. A little microperthite and calcite occur as accessory constituents, the latter mineral occurring as already described.

The New York Graphite Co. are reported to be erecting a mill about a mile from Mumford to treat the graphite secured from what is said to be a large and rich deposit of this mineral occurring in association with hornblende and pyroxene gneisses. In a cutting for the railway near the west end of Cardiff lake, the limestone of the Grenville series is again exposed, holding at this place both graphite and chondrodite. Further west, near the east end of Dark lake, the rock is cut by veins composed of orthoclase, biotite, calcite, etc., which were formerly worked for mica.

342·37 m. 551 km. **Wilberforce.** Alt., 1,194 ft. (363·9 m.).—Graphite occurs in many places in the Grenville limestone which underlies this district, and a large mill for the separation of this mineral has been erected here by the Virginia Graphite Co. There is an outcrop of highly graphitic limestone adjacent to the mill. This limestone contains, in addition to the graphite, a small amount of colourless pyroxene, microcline and sphene. The graphite-bearing rock—a graphitic

and micaceous limestone—treated by the mill is, however, brought from near Maynooth.

344·57 m. 554·7 km. **Monmouth Road.** Alt., 1,181 ft. (360 m.).

347·87 m. 560 km. **Toryhill.** Alt., 1,147 ft. (349·6 m.).

The Nepheline Syenite-Granite Intrusion in the Central Part of the Township of Monmouth.

In the vicinity of Tory-hill there is a large and very interesting occurrence of nepheline syenite, which is found as a border or marginal phase of a body of pegmatitic granite running through the centre of the Township of Monmouth in a direction about N. 30° E. for about six miles (9·6 m.). This granite mass has a maximum width of a little over one mile. The border of nepheline-syenite is from one-eighth to half-a-mile (200 to 800 m.) in width. The whole occurs as an intrusion into the white crystalline limestones of the Grenville series.

The granite is pink or red in colour and is usually of medium grain. It frequently shows the rapid variation in size of grain common in pegmatite. At the north-eastern end of the mass it is distinctly foliated. Further to the south this foliation becomes less distinct, but the rock presents a streaked appearance.

The feldspars present are albite, microperthite, orthoclase and microcline, the two first mentioned minerals predominating. The ferromagnesian constituents are present only in very small amount and consist of biotite and two varieties of hornblende.

The granite is nowhere rich in quartz, although in the north-eastern part of the mass this mineral is present in considerable amount. To the south-east this mineral decreases in amount and the rock assumes a syenitic facies.

This syenite is red in colour and is composed almost exclusively of feldspar, which is for the most part microperthite, the iron-magnesia constituents occurring in occasional dashes with rudely parallel arrangement. It differs from the granite not only in the fact that no quartz is visible in the thin sections but also in that hornblende is

absent. In the quantitative classification the rock is a phlegrose.

An analysis of the rock is given on page 96.

This syenite passes imperceptibly into the nepheline syenite on either side by an increase of soda feldspar. The transition is also well seen on the southern end of lot 15 of concession VIII of the Township of Monmouth at the corners near Hotspur post office. The nepheline syenite here has a schlieren structure caused by a variation in the relative amount of constituent minerals in the different streaks. Some of these schlieren consist of red syenite, others are intermediate in composition between red syenite and the nepheline syenite. There are thus represented in these schlieren a complete transition from the red syenite to the white or grey nepheline syenite.

The nepheline syenite which forms the border of the mass has a distinctly foliated structure and is coarse in grain. It is white to dark grey in colour according to the proportion of the ferromagnesian constituents which it contains. It usually possesses a rudely banded or schlieren structure which conforms in direction to the foliation of the rock, which in its turn conforms to the outline of the intrusion, that is to say, the foliation of the nepheline syenite strikes around the mass as does also the intruded limestone.

In the nepheline syenite some of the schlieren are rich in nepheline, while in adjacent schlieren nepheline is present only in small amount. A similar variation is to be observed in the case of the dark constituents of the rock. The party will examine this occurrence along two of the roads which cross it.

Leaving Tory hill the road running in an easterly direction will first be taken and followed for one mile. Along this road the white crystalline limestones are first seen in large exposures and are succeeded on lot 21 of range XI of the Township of Monmouth by large exposures of the nepheline syenite showing the usual schlieren structure and foliation, which in most places is rich in nepheline and coarse in grain.

The party will then return to the train which will proceed as far as McCue's crossing, and leaving the train will walk south to the corners near Hotspur post office, where they will take the road running in a westerly direction

to Hadley, where they will meet the train again. This represents a distance of five miles (8 km.)

The road going south from McCue's crossing first crosses drift with a few exposures of the white crystalline limestone protruding through it.

This is succeeded by the nepheline syenite, the actual contact of the rock with the limestone being obscured by drift. About the middle of the nepheline syenite belt, the road passes over an included body of limestone.

A variety of nepheline syenite rich in albite and poor in nepheline is exposed in the low cliffs on the east side of the road one mile north of Hotspur Corners on lot 16, range IX of Monmouth.

Under the microscope it is seen to possess a hypidiomorphic structure and to consist of the following minerals: Albite, microcline, microperthite, nepheline, lepidomelane, magnetite and calcite. In some few schlieren a dark green hornblende (probably hastingsite) replaces a portion of the biotite. Albite and lepidomelane are the chief constituents. The albite is well twinned and must be a variety approaching the pure soda molecule, as it has a specific gravity of 2·618 and shows a maximum extinction against the line of the twinning lamellae of 15°. In a single slide a few grains having an extinction as high as 20° were observed, showing that a plagioclase somewhat more basic than albite is also occasionally present in very small amount. The microcline presents its usual characters and is frequently intergrown with albite, forming microperthite. The nepheline is in large individuals similar in shape and dimensions to those of the albite. Smaller individuals of it are sometimes included in the albite, while in other cases it includes individuals of albite. It is very fresh and free from alteration products. The lepidomelane is the same dark brown, highly pleochroic variety of biotite which occurs in the transitional rock lying between the granite and the nepheline syenite and has the same form of short laths. A lighter coloured mica is also present in smaller amount. The calcite occurs in large single individuals, often rounded, sometimes enclosed in the feldspars, nepheline or lepidomelane, but usually lying between the other constituents. The enclosing minerals show no signs of alteration and the calcite shows no sign of secondary origin. The magnetite is in large subangular or more or less rounded grains. There seems to be no definite order

of succession in the crystallization, seeing that the various minerals enclose and penetrate one another. The lepidomelane, however, has a much better form than the other constituents and would thus seem to have crystallized earlier.

An analysis of the biotite-bearing variety is given on page 96. This nepheline syenite in the quantitative classification ranks as an essexose. It contains 3·45 per cent of calcite.

The road then passes further in toward the centre of the intrusion, affording excellent exposures of the red syenite described on page 55. Near Hotspur Corners the relation of the syenite and the nepheline on the western side of the mass will be seen.

Leaving this interesting intrusive mass, the road then continues in a westerly direction over limestone penetrated in one place by a small intrusion of granite to another intrusion of nepheline syenite and allied rocks, which is of interest.

Nepheline syenite intrusion in the western part of the Township of Monmouth.

This occurs on lots 9, 10 and 11 of ranges VII and VIII of the Township of Monmouth. It is a lenticular mass approximately one mile (1·6 km.) long and 700 yards (640 m.) across at its greatest width and is formed of a body of nepheline-bearing rock presenting an example of extreme differentiation. As usual in this district, these rocks have a marked foliation and are developed as a series of schlieren rudely parallel to one another and conforming to the strike of the enclosing limestone. Some of the schlieren are highly feldspathic varieties of nepheline syenite, but others contain little or no feldspar. Others are composed almost exclusively of nepheline, while still others consist essentially of nepheline and ferromagnesian constituents.

The following three varieties have been carefully studied:

(1) *Nepheline syenite* (*1st variety*).

This variety is coarse in grain, dark in colour and rich in hornblende. Under the microscope it is seen to consist of nepheline, albite, hornblende and calcite, with a small

amount of apatite as an accessory constituent. These minerals, with the exception of the apatite, are all in large individuals, and like most of the nepheline syenites of this area, have a peculiar structure which approaches an allotriomorphic structure in character. None of the minerals have good crystalline forms, but all have a tendency to occur with more or less rounded outlines and to come against one another in curved lines. Inclusions of one mineral in another are common, no definite order of succession can be observed in the crystallization, and the structure in some respects approaches the "mosaic" structure seen in the metamorphic rocks when a complete recrystallization has taken place.

The nepheline is considerably altered to a very fine-grained turbid aggregate resembling kaolin, but in places it is quite fresh and shows its usual optical properties. It frequently holds rounded inclusions of albite and of calcite. The albite is well twinned and possesses the usual characters. The hornblende is the most abundant constituent, and, if not hastingsite, is a variety closely resembling it. It is deep green in colour and looks black on the fractured surface of the rock. Although the rock is so basic, it contains no iron ore, which is elsewhere common as an accessory constituent in such rocks. The calcite, as usual, occurs as rounded inclusions in the albite, nepheline or hornblende, or filling spaces between the grains of these minerals. No microcline nor microperthite is present in the sections.

An analysis of the variety is given on p. 96. Under the quantitative classification it ranks as essexose. Its "mode" or mineralogical composition as calculated from the analysis is as follows:—

		Per Cent.
Orthoclase		2·78
Albite	22·27	23·94
Anorthite	1·67	
Nepheline	15·91	26·23
Kaolin	10·32	
Hornblende		39·75
Apatite		·34
Calcite		5·50
		98·54
Water		1·10
		99·64

(2) *Nepheline syenite* (*2nd variety*).

This is rich in nepheline and contains a large percentage of pyroxene. It is much lighter in colour, but otherwise bears a general resemblance to the variety just described. Under the microscope all the constituents are seen to be fresh, but they frequently show signs of having been submitted to pressure, as shown by the presence of a more or less uneven extinction. This is especially marked in the case of the calcite, and the albite can in some few instances be seen to have been not only bent but actually fractured. The nepheline also occasionally shows strain shadows. As before, no microcline nor microperthite is present in the sections and a Thoulet separation shows that the rock contains no potash feldspar. The albite has a specific gravity of very nearly 2·61.

The pyroxene is very deep green in colour and slightly pleochroic. Around the individuals of this mineral and occasionally about the calcite grains, there is sometimes a narrow border of garnet. The pyroxene is evidently very rich in iron and holds rounded inclusions of calcite and nepheline.

An analysis of the variety is given on p. 96. Under the quantitative classification it ranks as vulturose. Its "mode" or mineralogical composition as calculated from the analysis is as follows:—

Albite	19·39
Nepheline	50·57
Pyroxene	18·35
Garnet	1·45
Iron ore	1·86
Apatite	·34
Calcite	6·80
	98·76
Water	·88
	99·64

(3) *Monmouthite* (*3rd variety*).

This is the type locality for this rock which is allied to urtite, but differs from that rock in containing a rela-

tively small amount of ferromagnesian constituents. It is a nearly pure nepheline rock. It is coarse in grain and has a rudely foliated structure. On the weathered surface there is a marked contrast between the nepheline, with its smooth grey surface from which the accessory albite present stands out in chalk-white grains, and the black hornblende.

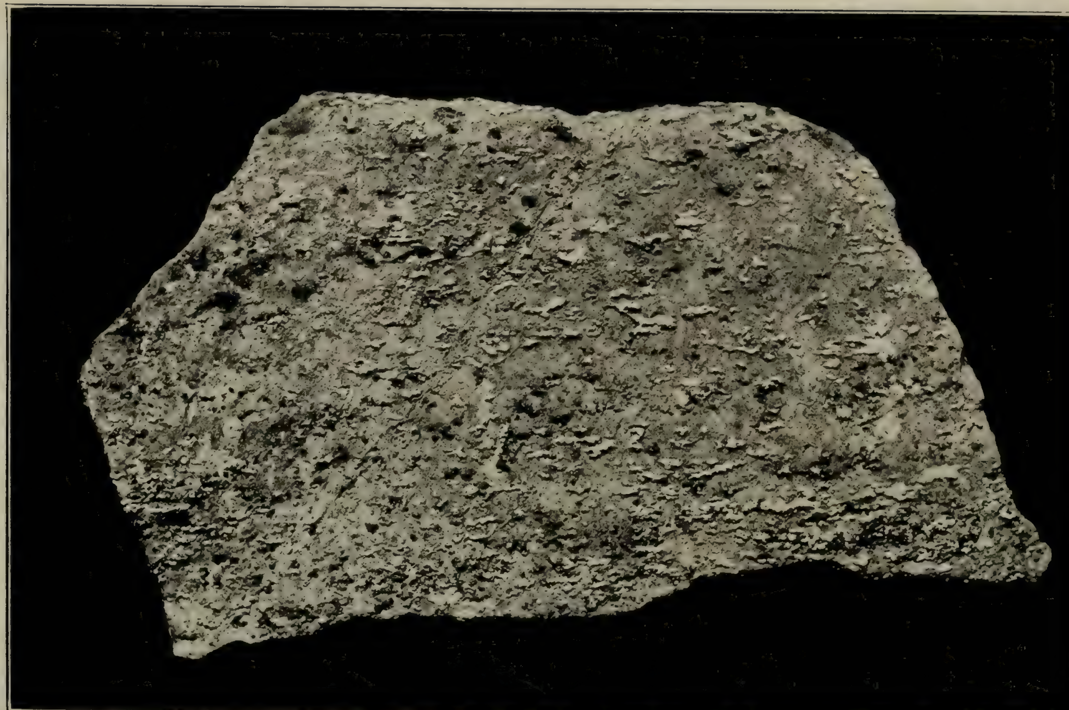
Under the microscope the rock is seen to consist of nepheline and hornblende, with albite, cancrinite and calcite as accessory constituents, as well as sodalite, apatite, sphene, biotite, pyrite and iron ore, these latter mainly being present in extremely small amounts. The rock is very fresh. The hornblende is a variety allied to hastingsite. The calcite occurs in large individuals which are found as inclusions in the nepheline and hornblende. The individuals are often circular in outline and the enclosing mineral is fresh and sharply defined against them. In other cases the calcite grains lie between the other constituents of the rock, but in all cases have the character of inclusions. They generally show marked strain shadows, while the other constituents of the rock show little or no evidence of pressure phenomena.

An analysis of the rock is given on p. 96.

The "mode" or percentage mineralogical composition of the rock calculated from the analysis is as follows:—

Albite	1·83
Nepheline	72·20
Sodalite	·28
Cancrinite	5·14
Hornblende	15·09
Hematite	·50
Calcite	3·12
Pyrite	·14
	98·30
Water	·50
Excess of Alumina	1·20
	100·00

The rock when described represented a new rang and sub-rang in the quantitative classification.



Monmouthite, lot 11, Con. VIII. Monmouth township. Nepheline (grey) with subordinate albite (white) and hastingsite (black).

In addition to these relatively fine-grained varieties, there are several fine exposures of nepheline syenite pegmatites holding calcite.

ANNOTATED GUIDE—continued.

Leaving this occurrence of nepheline rocks, the party will continue westward to Hadley, visiting en route a quarry in a fine-grained microcline granite on the line between lots 7 and 8, Cons. VII and VIII of the Township of Monmouth, from which paving sets are being taken.

351·97 m. 566·4 km. **Hadley,** Alt. 1,120 ft. (341·4 m.)—The party will again entrain at this railway crossing. Following Burnt river, there are only a few exposures before reaching Gooderham.

355·57 m. 573·8 km. **Gooderham,** Alt. 1,023 ft. (342·3 m.)—The railroad first crosses the Grenville limestone with an intrusion of nepheline syenite and then runs close to the contact of the limestone series with the Glamorgan granite batholith to Maxwell's Crossing.

361·27 m. 581·4 km. **Maxwell's Crossing.** Alt. 1,023 ft. (342·3 m)—In the rock cuttings on the railway at this place, certain characteristic contact phenomena of the intrusion of the Grenville limestones by the Glamorgan granite batholith are well seen.

CONTACT PHENOMENA IN THE VICINITY OF MAXWELL'S CROSSING.

The limestones are part of the south-western extension of the great belt which underlies the north-west corner of Monmouth and the eastern part of Glamorgan townships. The granite belongs to a great batholith which extends northward and westward into Dysart and Snowdon townships. The invading granite, in the form of apophyses, wanders through the limestone series in all directions, sometimes cutting across the bedding, but very frequently in the form of narrow dykes forcing its way between the beds of the invaded limestone, changing it into amphibolite and presenting a typical instance of *lit-par-lit* injection. The granite, furthermore, not only penetrates the series,

but floats off masses of the altered rock which, in the form of bands, streaks, and isolated shreds are seen thickly scattered through the granite in the vicinity of the contact, and which, while less abundant, are found throughout practically the whole extent of this batholith. The separate fragments of amphibolite, where completely surrounded by the granite, while clearly nothing more than masses of altered limestone, are rather harder and more "granitized" in appearance than the amphibolite which is still interstratified with the limestone, and the fragments sometimes have somewhat flowing outlines as if they had been subjected to a certain amount of movement when in a softened condition.

When examined in thin sections under the microscope the limestone which is in the act of passing into amphibolite is seen to do so by the development in it of certain silicates. These, when the change is complete, are so abundant that they entirely replace the calcite, while in the intervening stages some of the original calcite still remains. These silicates belong to the following species: pyroxene, hornblende, sphene, scapolite, plagioclase, microcline, orthoclase, and quartz. The relative abundance of these minerals varies in different bands and from place to place in the rock. Their characters are as follows:

The *pyroxene* is rather deep green in colour and non-pleochroic. It is one of the chief constituents, being present in large amount in the earlier stages of the change. It first appears in rounded individuals which possess neither crystallographic outlines nor any approximation to crystalline form. In those varieties rich in calcite, the sections of the pyroxene grains are frequently nearly circular.

The *hornblende*, which at first is much less abundant than the pyroxene, is also green in colour, but it is a much deeper green than the pyroxene. The grains are similar to those of the pyroxene in form, but are usually less rounded. It is intimately associated with the pyroxene, often forming adjacent grains, but there is no conclusive evidence that one mineral is derived from the other. It is strongly pleochroic.

The *sphene* is present only in very small amount in the form of small rounded grains of brown colour.

Scapolite is usually present in considerable amount. It polarizes in brilliant colours, is uniaxial and negative, and shows the other microscopical characters of this mineral.

The *feldspars* vary greatly in amount. In places they form a considerable part of the rock, while no scapolite is present. In other places the scapolite seems to take their place and they are reduced to the rank of accessory constituents. All three varieties of feldspar mentioned often occur in the same specimen, their relative abundance varying from slide to slide. The polysynthetically twinned plagioclase in some cases equals the potash feldspar in amount, but usually the potash feldspars seem to be rather more abundant.

Quartz is found only in a few of the thin sections and is then present only in very small amount.

When *calcite* survives, it can be seen that the original rock had the character of a coarsely crystalline limestone or marble. Under the action of the metamorphic processes the silicates have grown into it in the form of rounded grains which, increasing gradually in size, have finally left the calcite merely as a filling of the surviving interstitial spaces. The grains are about the same size as those of the other minerals.

An examination of thin sections of a suite of specimens of this amphibolite—some of them still containing little surviving bands of calcite and others of the harder and more altered varieties—shows that pyroxene and scapolite accompany the hornblende and feldspars in the former, while as the alteration becomes more pronounced these former minerals become less abundant and eventually disappear, giving rise to a rock composed of hornblende and feldspar, associated with which a little biotite is seen in some specimens and with certain accessory minerals common to both rocks. Although, as above mentioned, no actual passage of pyroxene into hornblende could be definitely observed, the hornblende individuals often have a minutely serrated edge where they come against the pyroxene, as if they were gradually enlarging themselves at the expense of the latter mineral and thus replacing it.

The amphibolite, representing the final product of the alteration, while possessing a more or less distinct foliation, has the "pflaster", "pavement", or mosaic structure characteristic of rocks which have resulted from recrys-

tallization brought about by metamorphic processes. It presents no evidence of crushing or of having been caused to move since its recrystallization took place. This structure is quite distinct and different from that seen in the little injected bands of granite. In these, which are composed of quartz, microcline, orthoclase and plagioclase, the quartz occurs for the most part in thin leaves with undulatory extinction and the structure of the rock is suggestive of the "mortel" or granulated structure seen in the granite gneisses.

In this remarkable occurrence, therefore, the crystalline limestone can be seen under the influence of the granite intrusion to have changed into a typical hornblende-feldspar amphibolite, having passed through the intervening stage of a pyroxene-scapolite-hornblende-feldspar amphibolite (pyroxene-scapolite gneiss).

Three specimens of these amphibolitic rocks from Maxwell's Crossing, chosen to represent three steps in the progressive change from limestone to amphibolite, have been analysed by M. F. Connor, of the Department of Mines. The figures given are in every case the mean of two determinations which agree closely with one another. The results of these analyses are as follows:—

	No. 1. (a)	No. 1. (b)	No. 2.	No. 3.
SiO_2	32·88	50·20	50·00	50·83
TiO_2	0·49	0·75	0·82	1·10
Al_2O_3	9·04	13·80	18·84	18·64
Fe_2O_3	0·77	1·18	2·57	2·84
FeO	3·48	5·31	5·51	5·97
MnO	....	....	0·08	0·10
CaO	30·90	17·71	10·65	7·50
MgO	4·18	6·38	4·63	4·90
K_2O	0·85	1·30	1·18	1·83
Na_2O	1·17	1·79	4·46	4·22
CO_2	15·20	....	0·10	0·11
Cl	undet.	....	0·10	0·03
S	undet.	....	0·03	0·01
H_2O	1·08	1·66	1·00	1·40
	100·04	100·08	99·97	99·48

No. 1 represents the first stage of alteration, and was made from a specimen which shows an alteration of narrow, lighter and darker coloured bands. The specimen was broken across the strike of the rock and thus included several of each of these bands, giving in this way an approximate average of the composition of the rock as a whole. Under the microscope the lighter coloured bands are seen to consist of calcite, pyroxene and a little hornblende. In the darker bands the calcite is largely replaced by the silicates, the constituent minerals of these bands being scapolite, pyroxene, some hornblende, some calcite, and a little microcline. A very small amount of sphene is also present in the rock.

The analysis as given under No. 1 (a) represents the composition of the specimen as collected; that given under No. 1 (b) represents the composition of the rock as it appears when the calcite present (determined by calculation from the amount of CO_2 present and also by direct experiment) is deducted and the amount of the remaining constituents is recalculated on the basis of 100. No. 1 (b) therefore represents the percentage composition of the silicated portion of the specimen, or, to put it in another way, it represents, except in the case of the lime, the additions made to the limestone by the granite magma in this first stage of alteration. The specimen contains 34·50 per cent. of calcite, leaving 65·50 per cent. of silicates. This silicated portion of the rock, as will be seen by comparing analysis No. 1 (b) with Nos. 2 and 3, bears a general resemblance in composition to the two latter rocks, which represent the subsequent stages of alteration, the percentage of silica being practically identical in all cases.

No. 2 is the analysis of a typical specimen of the amphibolite which alternates with thin bands of the limestone at Maxwell's Crossing. It represents a second stage in the alteration, this particular specimen being practically free from calcite. Under the microscope it is seen to be composed of hornblende and pyroxene, more or less completely replacing each other in the alternate bands, together with a considerable amount of scapolite, plagioclase and untwinned feldspar. The rock also contains many minute rounded grains of sphene scattered everywhere through it, but holds no iron ore and no biotite.

No. 3 is the analysis of a harder variety, a typical amphibolite representing the last stage of the change. It

occurs as an inclusion in the granite in the same series of exposures as that from which the other specimens were taken. The field relations show that it has been derived from variety No. 2 by further alteration. Although not differing much from No. 2 in chemical composition, under the microscope it is seen to differ considerably from it in structure, the individuals of the several constituents showing a less marked tendency to a rounded outline than in the case of No. 2. In mineralogical composition also it presents certain differences, the pyroxene and scapolite having disappeared and a certain amount of biotite having been developed.

A comparison of the analyses shows that the granite at first transfuses into the limestone, silica, alumina, oxides of iron and magnesia, with some alkalies and a small amount of titanic acid. As the alteration progresses, all these constituents continue to increase in amount. But in these later stages of the alteration the alumina, oxides of iron, and alkalies are added in relatively greater proportion than the other constituents, while no further addition of magnesia or lime takes place, the proportion of these constituents remaining essentially the same, the carbonic acid escaping and carrying the rest of the lime with it.

This means, speaking generally, that pyroxene and some scapolite were first developed in the limestone and that later the feldspathic constituents increased in amount, the calcite present being removed in solution.

A calculation of the analysis shows that Nos. 1 (b) and 2 have the following mineralogical composition:

—	No. 1 (b)	No. 2.
Feldspathic constituents	48·57	67·35
Pyroxenic (iron magnesia) constituents	46·63	26·28
Iron ores	3·2	5·27
	98·40	98·90
Water	1·66	1·00
	100·06	99·90

During the change of No. 1 into No. 2 and this into No. 3, the information afforded by the analyses bears out that obtained from the study of the thin sections, showing that there has been a very considerable rearrangement among the constituents of the rock. Thus it is seen that while the alumina and alkalies increase in No. 2 and No. 3 there is not a corresponding increase in the total amount of silica; the silica required to make additional feldspathic constituents is derived from some other reactions going forward in the rock.

It seems also that after the development of a certain percentage of silicates in the limestone, as shown in No. 1, during which process carbonic acid was expelled and the lime combined with it used in the production of new minerals, no further lime was fixed. In the earlier stages the waters given off by the granite having accomplished the transference of material in the limestone, passed off with the replaced CO_2 in solution, leaving the lime behind. In the later stages of the alteration, however, these waters while continuing to deposit silicates in the limestone, made place for them by carrying off carbonate of lime in solution.

As will be seen, the difference in chemical composition between Specimen 2 and Specimen 3 is very small. The more highly altered rock, No. 3, is rather richer in iron, magnesia, and alkalies, while it is considerably poorer in lime and contains less chlorine. These difference are seen to represent a slight increase in the proportion of hornblende and orthoclase present and a decrease in the amount of plagioclase and scapolite in the rock.

If, for the purpose of comparing the composition of these alteration products with that of igneous rocks, the norms are calculated, these are found to be as follows. Since No. 3 is essentially the same as No. 2, the norm of the latter rock may be taken to represent both specimens and with it is given the norm of the silicated portion of No. 1 (No. 1 (b)).

—	No. 2.	No. 1 (b)
Orthoclase	7·23	7·74
Albite	26·20	15·24
Anorthite	27·94	25·59
Nepheline	5·56	....
Sodalite	0·42	....
Diopside	19·78	34·81
Akermanite	....	6·97
Olivine	6·30	4·85
Calcite	0·20	....
Ilmenite	1·52	1·40
Magnetite	3·71	1·80
Pyrite	0·04	....
	98·90	98·40
Water	1·00	1·66
	99·90	100·06

In the quantitative classification the rocks, therefore, have the following position:—

No. 2.		No. 1 b.	
Class II	Dosalane	Class III	Salfemane
Order 5	Germanare	Order 5	Gallare
Rang 3	Andase	Rang 4	Auvergnase
Subrang 4	Andose	Subrang 4	Auvergnose

While, therefore, the quantitative classification is intended to apply only to igneous rocks, this final product of the metamorphism of the limestone when compared with igneous rocks readily takes its place as an andose, a group which includes many rocks which are commonly known as diorites, gabbros, basalts, diabases and essexites.

For purposes of comparison the analysis of this amphibolite (No. 2) is here repeated together with that of an amphibolite (No. 5) produced by the alteration of a basic igneous intrusion (probably a diabase originally) and with the analyses of three other typical igneous rocks which have been produced by the solidification of molten magmas.

—	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
SiO_2......	50·00	48·81	50·86	50·73	48·85
TiO_2......	0·82	0·74	....	1·59	2·47
Al_2O_3.....	18·84	16·62	15·72	19·99	19·38
Fe_2O_3.....	2·57	1·17	9·77	3·20	4·29
FeO......	5·51	7·47	2·48	4·66	4·94
MnO.....	0·08	0·12	....	0·05	0·19
CaO......	10·65	10·30	10·52	8·55	7·98
MgO......	4·63	8·28	3·55	3·48	2·00
K_2O......	1·18	0·76	0·90	1·89	1·91
Na_2O.....	4·46	3·31	3·89	4·03	5·44
CO_2.......	0·10	0·55	....	....	....
Cl........	0·10	0·03	....	....	not det.
S.........	0·03	0·06	....	....	....
P_2O_5......	....	....	....	0·81	1·23
H_2O......	1·00	0·95	2·53	0·77	0·68
	99·97	99·17	100·22	100·13*	99·36

*Including BaO 0·27.

No. 4. Amphibolite resulting from the alteration of limestone—Maxwell's Crossing, Lot 5, Range VI, Township of Glamorgan, Ontario.

No. 5. Dyke cutting limestone—Lot 27, Range VIII, Township of Methuen, Ontario.

No. 6. Gabbro, near Baptism river, Minnesota, U.S.A. (Wadsworth, Geol. Survey of Minn., 2 p. 79, 1887).

No. 7. Diorite—Big Timber creek, Crazy mountain, Montana (Wolff, Bull. U.S.G.S., 148, p. 144, 1897).

No. 8. Normal essexite—Mount Johnson, Quebec (Adams, Jour. of Geol., April-May, 1903.)

In connection with this alteration of limestone to amphibolite it is to be noted that the change is not one of solution or digestion of the limestone by the granite, for the fragments preserve their sharp and well-defined forms even when the alteration is complete.

The limestone, at a distance from the granite, is a white crystalline marble, containing scarcely any impurities and effervescing freely in fragments with cold dilute hydrochloric acid, showing that it is an essentially pure carbonate of lime.

The changes are the result of the transfusion into the limestone of certain constituents which are present in the granite magma. A remarkable fact in connection with the alteration, is that the granite, which is an acid variety of the rock containing a very small amount of biotite as its only bisilicate, where the limestone was bathed by it or

Amphibolite resulting from alteration of limestone, cut by pegmatite. Eastern border of Glamorgan batholith near Bear lake.

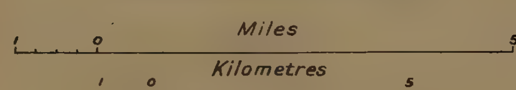
actually immersed in it as in the case of the included fragments, has notwithstanding this fact transfused into the limestone not only silica, alumina and alkalis, as might be expected, but also large amounts of magnesia and iron. The limestone evidently fixed certain constituents of the granite magma in relatively greater abundance than others, exerting a species of selective action.

In the cutting just west of Maxwell's Crossing there is an exposure of a coarse pegmatite rather rich in ferromagnesian constituents, holding an inclusion of limestone

A2.

Geological Survey, Canada

Gooderham and Vicinity



into which the constitutens of the pegmatite have grown with well defined crystal faces.

Geology in the Vicinity of Gooderham.

From the road crossing about one and a half miles (2·4 km.) to the east of Gooderham station, the party will walk southward for two and a half miles (4 km.)

This road in the first half mile crosses a sand plain through which Burnt river meanders. Then the party will cross lot 30 of Con. V. of the Township of Glamorgan by a trail leading southwards, passing over crystalline limestone to a large occurrence of an albite-rich variety of nepheline syenite containing a hornblende allied to hastingsite. This rock is distinctly foliated, of medium grained texture, with schlieren of coarse grained nepheline syenite pegmatite. The micaceous constituent is biotite, not lepidomelane.

This is succeeded by crystalline limestone penetrated by masses of a remarkable nepheline syenite pegmatite. One exposure on lot 30, Con. IV, has been opened up by blasting. The rock, as shown in the accompanying illustration, consists essentially of nepheline and albite, with occasional individuals or small masses of coarsely-crystalline calcite. The iron-magnesia constituents—chiefly biotite—are present in very small amount, and over large surfaces are entirely absent. A black hornblende, as well as a little pyrrhotite, may also be seen. The rock contains masses of pure nepheline which in places measure a yard in diameter. Sodalite is also occasionally represented as irregular masses sometimes two inches in diameter, included in the large masses of nepheline and having apparently been derived from them by secondary action.

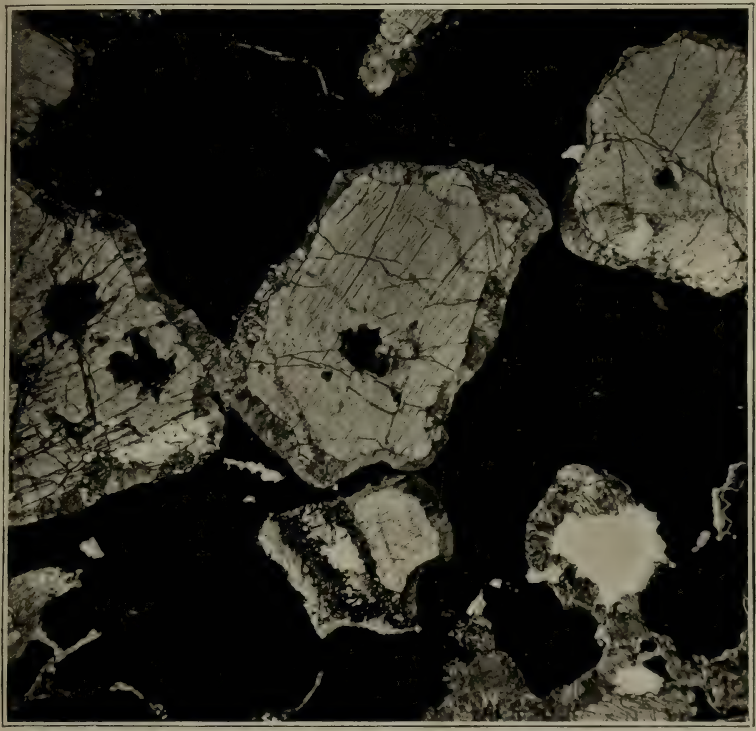
The party will then go to a point by the roadside on lot 29 of Con. III, where a good view over the district to the north can be obtained, and whence, on a clear day, the character of the peneplain can be seen (see p. 11.)

The country rock at this point shows one phase of the gabbro of a great intrusion which underlies a large area of the country to the south. This intrusion has a length of eight miles (12·9 km.) and a maximum width of two and a half miles (4. km.). The gabbro composing it shows a very marked variation in composition from place to place, ranging in character from a rock in which plagioclase pre--

Nepheline syenite pegmatite, showing characteristic weathering, from lot 30, Con. IV. Glamorgan. Nepheline with albite (standing out on weathered surface). The cavities in the surface of the nepheline are caused by the weathering out of calcite.

ponderates largely through increasingly basic varieties to a pyroxenite and an iron ore. No regular order is observable in the distribution of these varieties.

The party will not have time to visit the occurrences of iron ore in question, but some large blocks of it have been brought out to the main road and from an examination



Pusey's iron ore. Glamorgan, lot 35 of con. IV (X 19 diam.) Pyroxene individuals enclosed in iron ore. About each pyroxene there is a narrow border of hornblende.

of these its character may be seen. It is a titaniferous iron ore, containing a small percentage of vanadium, as shown by the following analysis:—

Fe_2O_3	39·27
FeO	21·73
MnO	·37
Ni_8O	·27
CoO	·07
Al_2O_3	4·61
SiO_2	10·77
P_2O_5	·02
S	·11
TiO_2	13·52
V_2O_5	·52
MgO	2·34
BaO	·07
CaO	4·84
Na_2O	·31
K_2O	·24
Moisture	·44
Total	99·50

Under the microscope this ore is seen to consist essentially of titaniferous magnetite and pyroxene. The pyroxene individuals are enclosed in the titaniferous magnetite, but about each individual of pyroxene there is a narrow border of brown and usually highly pleochroic hornblende. The structure is well shown in the accompanying microphotograph.

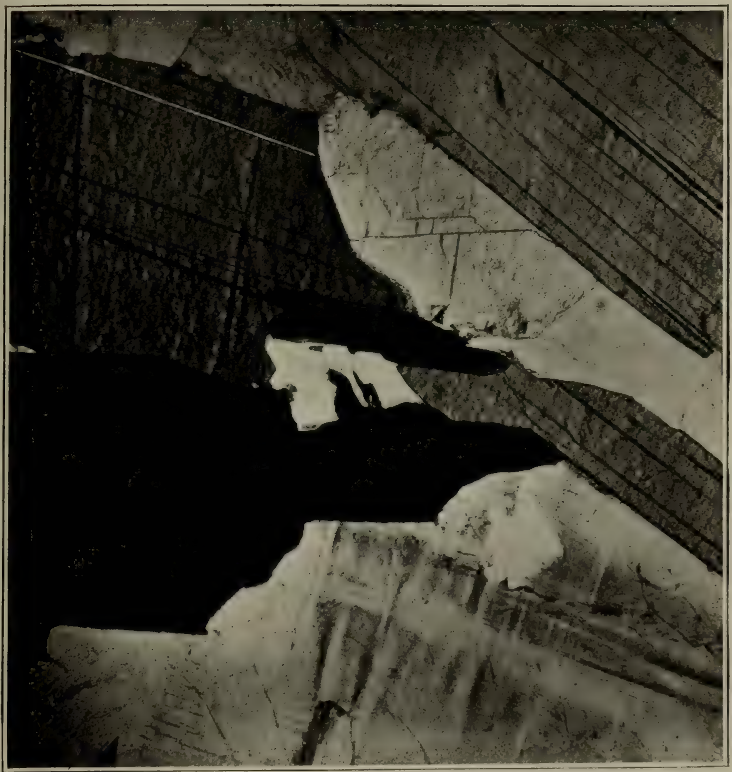
The party will then visit an interesting occurrence of nepheline syenite which appears on lot 32 of Con. III, Glamorgan township. This nepheline syenite, which is exposed on the road, is very fresh and represents a variety which is very distinctly foliated and dark in colour. Nepheline and hornblende preponderate largely in the rock, the feldspar being subordinate in amount. The hornblende has the optical properties of hastingsite and the feldspar is albite. The rock also contains some grains of calcite, rounded in form and occurring as inclusions in the other constituents of the rock. They are clearly not of secondary origin but are similar in character to those found in the nepheline syenites in other parts of the area as already described (see pp. 58-62).

An anlaysis of the rock by M. F. Connor of the Department of Mines is given on page 96).

Miles and Kilometres.

403·7 m.
649·6 km.

Bancroft. From Bancroft the party will drive to Bronson's Landing on York river. The region traversed is underlaid almost wholly by nepheline and associated alkali syenites



Nepheline syenite from lot 32, Con. VI, Glamorgan township, showing biotite, nepheline and microcline, with two included grains of calcite.

with some included masses of crystalline limestone. The original hastingsite was found in the nepheline syenite near this road about 2 miles (3·2 km.) from Bancroft. The latter part of this journey, after leaving the main

road (about 5·5 miles (8·8 km.) from Bancroft), is through the old Egan or Bronson farm, an old lumber depot and farm owned by the lumbering firms whose names it has borne. It is now known as the Lancaster farm, from the name of its present owner. A now deserted lumber road connects the farm buildings with the old camping ground on York river still known as Bronson's Landing.

410·37 m.
660·4 km. **Bronson's Landing.** At this place the party will embark in canoes for the trip down York river. York river or York branch of Madawaska river, as it is sometimes called, was formerly known as Shawashkong river. As the last mentioned name implies, it flows through extensive marshy flats, especially along its lower and upper reaches. It may here be mentioned that for the first ten or twelve miles below Bronson's Landing the stream flows through a region which still preserves the general character and aspect possessed by the primeval forest before the coming of the white men. The river was well known to the early inhabitants, and was much used by Indian hunting and war parties. Most, if not all, the pine trees have been removed by the lumberman, but the river banks are thickly wooded to the water's edge, principally by maple. elm, ash, balsam and spruce. The red deer is a very frequent visitor to the river and is by no means a rare sight to those ascending or descending the river in canoes. Muskrats, rabbits, porcupines and other small wild animals may also be seen, especially in the early morning or evening. The largest of the canoes used by the party on this present trip is similar in size and material to those in use by the brigades of the Hudson's Bay and Northwest companies in the fur trade and is an exact model of the canoe used by Sir George Simpson, Governor of the Hon.. Hudson's Bay Company in his memorable voyage from Hudson's bay to the Pacific ocean in 1828.

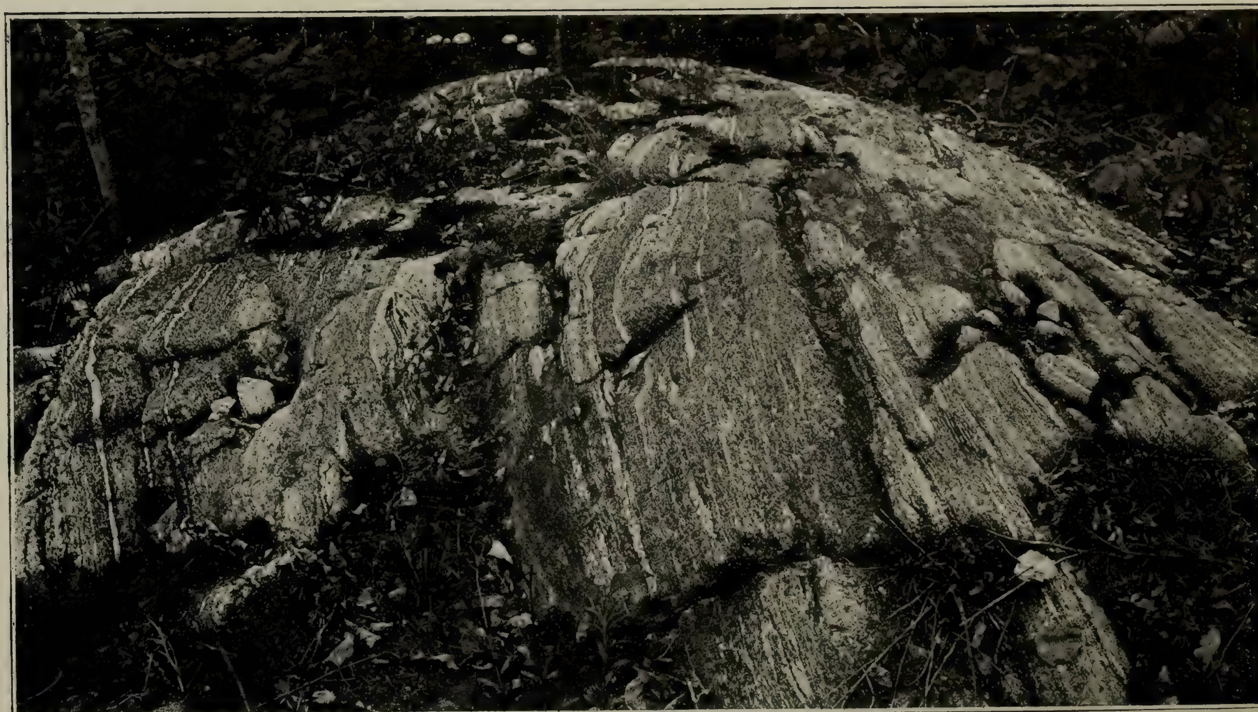
The stream, in its somewhat tortuous course, flows with a gentle current between low banks of drift and alluvium. In places the underlying crystalline limestones with associated alkaline syenites outcrop, but there are comparatively few exposures in the immediate vicinity of the river banks. For a distance of nearly 17 miles (27·3 km.) from Bronson's Landing to the head of Foster's rapids, there is uninterrupted and comparatively deep water suitable for the passage of canoes and other small craft.

The Occurrence of Dungannonite.

In the Township of Dungannon, Cons. XIV and XV, lot 12 is the locality from which the original dungannonite, a corundum-bearing alkali syenite with accessory nepheline, was obtained.

The typical dungannonite contains nepheline only in small amount and as an accessory constituent. Associated with it in the same series of exposures, however, there are differentiation phases of the magma which are rich in nepheline, the nepheline syenite thus resulting having as its essential constituents nepheline, plagioclase and biotite. This rock in places contains dark basic patches which are rich in hornblende, as well as others of a yellowish colour which contain an abundance of scapolite. The whole series has a well-defined foliation striking N. 25° E.

The dungannonite under the microscope is seen to be made up largely of plagioclase having the composition of andesine. Next to this feldspar corundum is the most important mineral constituent. Scapolite is also present, usually in subordinate amount, the larger individuals occupying the interspaces between the feldspars. Biotite is present in small amount, while muscovite occurs both intergrown with the biotite and as mantles of variable width surrounding the corundum individuals. This muscovite is regarded as a primary constituent formed at a time immediately preceding the complete solidification of the magma. Occasional grains or imperfect crystals of magnetite, with a small amount of calcite, complete the



Nepheline syenite showing regional foliation. Near York River bridge, lot 13, Con. XII. Dungannon township.

list of minerals found in the thin sections of this rock. The corundum is often very abundant. Some of the individuals show a nearly perfect crystallographic development, but the mineral as a general rule occurs as imperfect crystals or as irregular grains. It frequently shows very distinctly the parting planes parallel to the faces of the rhombohedron and the base. The colour varies even within the same individuals; the mineral has usually a distinct and often pronounced sapphire blue colour, but the corundum is sometimes white or brown in colour. The individuals of corundum frequently have a distinct corona of muscovite surrounding them, although this is not invariably present. The corundum is by no means uniformly distributed through the rock. A large portion of the rock is completely free from this mineral, while other areas, rather ill-defined in shape, contain a very high percentage of it. In outcrops exposed to the weather the corundum becomes very conspicuous, weathering out as it does in pronounced relief from the surface of the rock. In some places characteristic barrel-shaped hexagonal crystals, several inches in length, may be seen on these weathered surfaces. In the freshly broken rock, on the other hand, the corundum is detected only with difficulty, unless it assumes the usual bluish colour which enables it to be readily distinguished from the other constituent minerals of the rock.

In the exposures these rocks are seen to be cut through in various directions by dykes of fresh red pegmatite composed chiefly of red feldspar (orthoclase), microperthite and quartz, with a little hornblende. In some places imperfect crystals of this last-named mineral can be found which measure from 4 to 6 inches (10 to 15 cm.) in diameter. These dykes are evidently differentiation forms of a red syenite, which occurs in considerable volume immediately to the south of these exposures, and which is probably a somewhat quartzose type of the normal red variety of alkali syenite.

An analysis of this rock was made by Prof. Norton-Evans, with the following results, under I.—

Dyke of nepheline syenite pegmatite, cutting nepheline syenite parallel to the foliation, lot 25, Con. XIV. Dungannon township.

—	I.	II.	III. Molecular	III. Ratios.
SiO_2	49·56	58·32	·972	·972
Al_2O_3	33·70	23·80	·233	·240
Fe_2O_3	·93	1·09	·007	
FeO	1·42	1·67	·023	
CaO	5·89	6·67	·119	
MgO	·97	1·14	·029	·280
K_2O	1·23	1·44	·015	
Na_2O	4·95	5·83	·094	
CO_2	·17			
H_2O	·84			
	99·66			

Deducting the excess of alumina present as corundum, which was determined by trial, neglecting the loss on ignition(H_2O) and deducting the amount of lime (CaO) necessary to form calcite with the CO_2 in the rock, the results given under II are obtained. This is the composition of the residual or alumina-saturated magma.

Morozewicz [**9**, p. 1 and 105] has shown by direct experiment that in super-saturated alumino-silicate magmas, whose general composition is RO, n Al_2O_3, SiO_2 (where $R = K_2$, Na_2 or Ca; and n = 2), the whole of the excess of alumina separates out (1) as corundum if no considerable amount of MgO or FeO is present and if **n** is less than 6; (2) as sillimanite and corundum if **n** is greater than 6; (3) when the magma is rich in magnesia, as spinel or spinel and corundum, if **n** is less than 6; (4) as cordierite or cordierite with one or more of the other minerals if **n** is greater than 6. The absence of corundum in the nepheline syenites of India is explained by Holland as due to the fact that this rock, as shown by analysis, contains too much MgO and FeO, and he refers to the abundance of iron-magnesia minerals in the nepheline syenite, and the scarcity of such minerals in the corundum syenite, as amply accounting for the abundance of free alumina in the latter and its absence in the former. A similar low content of iron and magnesia is noticeable in the Canadian corundum

syenites, and, together with the high percentage of alumina in the magma, probably explains the development of corundum in them.

The ratios of the molecular values of (CaO, K_2O, Na_2O) : Al_2O_3 : SiO_2 in the rock at present under consideration are as follows:—

·222	:	233	:	972
1	:	1	:	4·2

The ratio of K_2O : Na_2O = 1 : 6 and alumina to the bases is a little in excess of 1 : 1. As a magma for the solution of alumina and its complete separation as corundum on crystallization, it is therefore in perfect agreement with Morozewicz's law. Of the alkalies, soda largely predominates, this lending the necessary assistance in the solution of the alumina. There is an excess of ferrous iron and magnesia above what has been thought permissible (0·05 per cent) by Morozewicz's law, but these amounts have been necessary to assist in the formation of the comparatively small quantities of magnetite and biotite present in the rock. It is therefore evident that Morozewicz's law, as remarked by Holland [**7,** p. 208] does not represent the whole truth, for it might be expected, with this excess of ferrous iron and magnesia, that spinel would be formed in addition to the corundum. This mineral was, however, not seen in the thin sections, nor was it found in any of the outcrops in the vicinity where this rock specimen was collected.

The norm of the rock is as follows:—

Quartz	1·26
Orthoclase	7·23
Albite	41·92
Anorthite	29·19
Corundum	13·46
Hypersthene	4·12
Magnetite	1·39
Calcite	·37
	98·94
Water	·84
	99·78

In calculating this norm from the chemical analysis, there was, as shown, an excess of 1·26 per cent of silica

above that required and which appears in the norm as quartz. By direct experiment it was subsequently shown that most, if not all, of this silica was derived from the agate mortar and pestle which was used in grinding the sample. There is no free silica or quartz shown in the thin sections, nor was any of this mineral found in the separation of the rock by means of the heavy solution.

The mode or actual mineralogical composition cannot be calculated with certainty on account of the presence of the two micas and the scapolite, the latter having about the same formula as the feldspar. The corundum, magnetite and calcite are normative, that is, they are present essentially in the percentages given in the norm. From an inspection of the slides the following would seem to be a very close approximation to the mineral composition of the rock:—

Andesine (near Ab_3An_2).........	72·00
Nepheline......................	3·00
Scapolite......................	2·00
Corundum (by trial)............	13·24
Biotite........................	5·00
Muscovite......................	3·00
Magnetite......................	1·39
Calcite........................	·37
	100·00

Owing to the large percentage of corundum present, the rock is a very peculiar and unusual one, and when discovered occupied a new sub-class, order, rang and sub-rang in the quantitative classification. The following names were accordingly proposed for the new rang and sub-rang, and the name dungannonite for the rock itself:—

Class I........................	Persalane.
Sub-class II (section I).........	Dosalane.
Order 5........................	Indare [13p.217]
Rang 3........................	Dungannonase.
Sub-rang 4.....................	Dungannonose.

An analysis of the andesine occurring in the rock was made by M. F. Connor. This is given under I. The material for the analysis was obtained by separating the feldspar with Thoulet's solution, but was somewhat impure, owing mainly to the admixture of a small amount

of biotite. This accounts for the iron, potash and magnesia found in the analysis. Neglecting these the composition corresponds rather closely to that of an andesine with the formula Ab_3An_2, with 0·96 per cent too little of silica and 1·68 per cent too little of lime. The specific gravity for such a mixture should be 2·68, while that of the andesine separated from the rock was 2·668, this slight decrease in weight being, no doubt, due to the unusually low lime. For purposes of comparison, the theoretical composition of andesine corresponding with the generally accepted formula for this species of plagioclase with the ratio of the soda to the lime of 1 : 1 (Ab_2An_1). is given under II, while under III is quoted the composition of andesine, made up of a mixture of albite and anorthite in the ratio of 3: 2.

—	I.	II.	III.
SiO_2	57·15	59·84	58·11
Al_2O_3	26·74	25·46	26·6
Fe_2O_3 / FeO	0·25		
CaO	6·66	6·97	8·34
MgO	0·59	.....	.....
MnO	trace	.....	.....
K_2O	0·38	.....	.....
NaO	6·83	7·73	6·93
H_2O	0·90	.....	.....
	99·50	100·00	100·00
Specific gravity	2·668	2·671	2·680

An analysis of the blue corundum which occurs associated with this rock was made by Mr. M. F. Connor, with the following results:—

SiO_2	none.
Al_2O_3 (diff.)	96·90
Fe_2O_3+FeO	0·76
CaO	0·46
MgO	1·00
H_2O	0·88

In the Township of Monteagle, Cons. I and II, lots 2, 3 and 4 are other outcrops of dungannonite very similar in composition to those already described as occurring in the township of Dungannon. The exposures are in the form of a comparatively narrow ridge or ridges, for the continuity of the ridge is broken at one point by a ravine which is traceable for a little over half a mile. The rock is very distinctly foliated and often schistose, bands of light and dark grey alternating with one another. Most of the exposed surfaces show crystals and aggregates of corundum in strong relief, this mineral having resisted weathering processes better than the other constituents of the rock. Near the southern end of the ridge a dyke a few feet wide crosses this gneissic syenite. It is composed of large individuals of nepheline and muscovite and small patches of blue sodalite.

ANNOTATED GUIDE—Continued.

Miles and kilometers.

422·77 m. 680·4 km. **Norway Bay**—Alt. 948 ft. (289 m.)—is a small bay-like expansion on the west side of the river.

424·52 m. 683·2 km. **Papineau creek**—Alt. 947 ft. (288·7m.)—enters the river from the north-west.

426·77 m. 686·7 km. **Foster's rapids,**—Alt. 946 ft. (288·4 m.)—have a fall of about six feet (1·82 m.), where a portage of nearly a quarter of a mile on the north side of the river, is often necessary, especially during low water, To the north of the clearing on this portage very basic nepheline rocks occur, while boulders of nepheline syenite occur in the clearing. Between Foster's rapids and Conroy's rapids, the stream is in places shallow and rapid owing to an accumulation of boulders.

429·02 m. 690·4 km. **Conroy's rapids,**—Alt. 936 ft. (285·3 m.) with a fall of three feet (·91m.) are in front of the old farm known as Campbell's farm. A short distance below these rapids the river widens and flows through a great swamp often known as "Campbell's marsh."

From the foot of Conroy's rapids,—Alt. 933 ft.; (284·4 m.)—the party to Combermere where the night will be spent, passing through Camp-

bell'smarsh, an expansion of York river which has been flooded by a dam at Palmer's rapids on Madawaska river (of which York river is a branch). The hills on either side are of the prevailing granite gneiss with inclusions of amphibolite and occasional areas of the Grenville series. In the vicinity of Craigmont a wide band of nepheline and alkali syenites crosses the river.

435·52 m. **Combermere** or "The Bridge" (Alt. 931 ft.
700·9 km. 283·8 m.) as it is sometimes called was an important and busy village in former years when lumbering operations were being actively prosecuted in this district. The party will spend the night here and in the morning will return on the steamer to Francois point.

442·62 m. **François point**—Alt. 931 ft.; (283·8 m.),
712·3 km. is the landing place for Craigmont. From here the party will walk or drive to Craigmont.

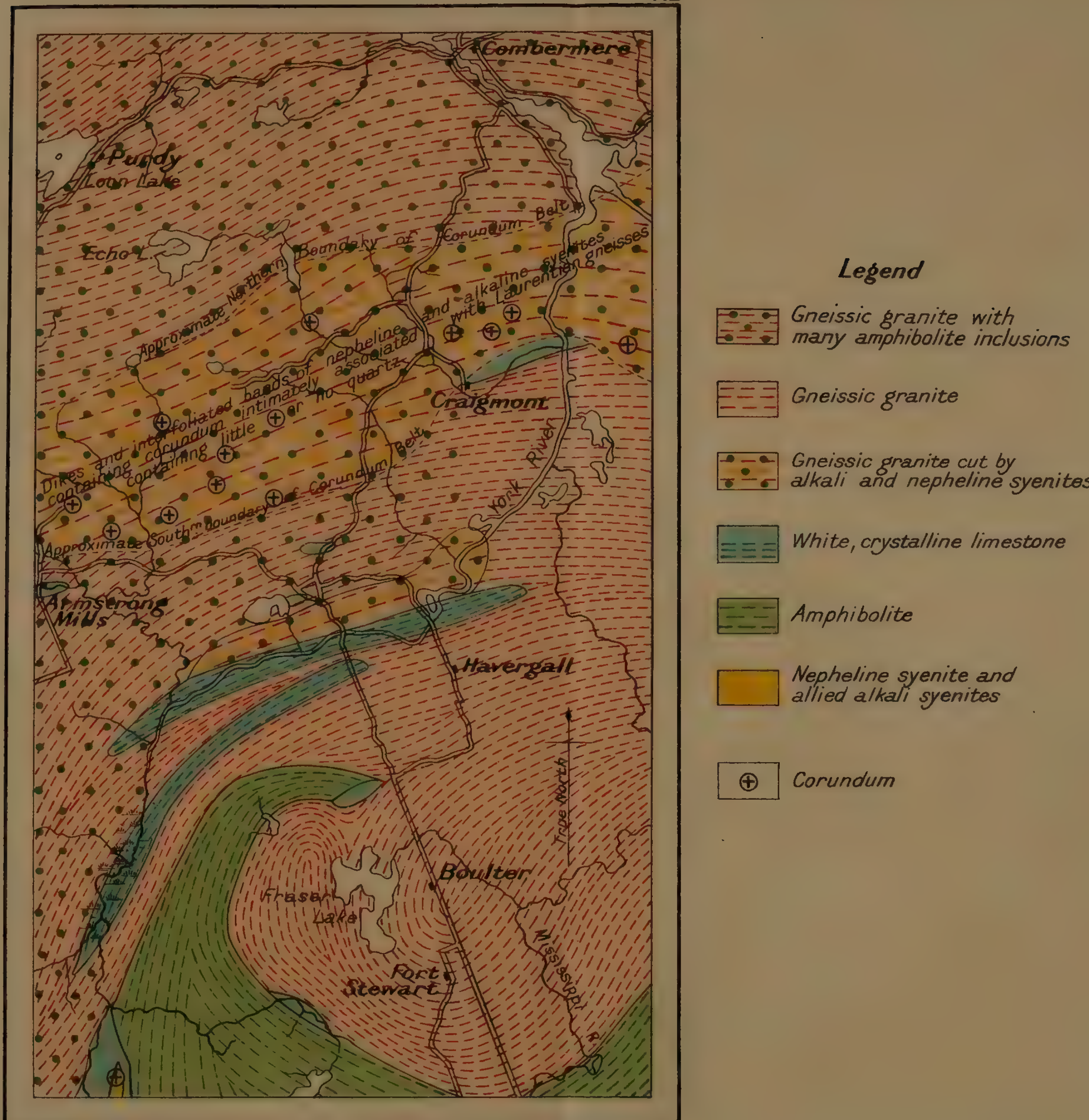
444·87 m. **Craigmont,**—Alt. 1426 ft. (434·6 m.).
715·9 km.

Geology of the Vicinity of Craigmont.

Craigmont (formerly Robillard mountain) is a well marked topographical feature rising abruptly from Campbell's marsh and extending as far west as the post road between Combermere and Fort Stewart. It covers most of the first four lots in Cons. XVIII and XIX, Raglan township, the line between these two concessions running along the southern slope of the mountain. According to the mean of several observations with two aneroid barometers, it is 595 feet (181·35 m.) above the marsh or 1426 feet (434·6 m.) above mean sea level.

The northern portion of the "mountain" is composed of the reddish granite-gneiss of the Laurentian batholith so prevalent throughout the region. This gneiss is well banded as well as very distinctly foliated and contains the usual amphibolite inclusions, for the most part elongated in the direction of the strike. This granite gneiss is intruded by many dykes and masses of granite pegmatite, often with a very marked "augen", probably a protoclastic structure, induced in the rock mass during the

A2



Geological Survey, Canada.

Craigmont Corundum Belt

Miles: 1 0 2 4 6

Kilometres: 1 0 3 6 9

Geological Survey, Canada.

Craig Mine, Raglan Township, Ontario.

Feet

100 0 500 1000 1500

Metres

100 0 200 400

later stages of its consolidation. The granite gneiss contains quartz while the granite pegmatite is often quite rich in this mineral.

The gneissic granite series to the north of the hill, by a gradual decrease in quartz, seems to merge into the corundum-bearing series which overlies it and which form the summit and southern slope of the hill. The corundum-bearing series is a complex of diverse though closely related rock types, differentiation products of one highly alkaline and aluminous magma and representing one phase of plutonic activity. These different rock types usually occur in irregularly sinuous, rather ill-defined bands, the gradual transition from one type to another being a distinctive characteristic of this occurrence. They are usually foliated, the strike being N. 75° E. with a dip to the south at an angle of 10°-12°. These rocks are intersected by dykes and masses of syenite pegmatite, which are very frequently parallel to the foliation, merging into the normal or finer grained types. Superimposed upon this corundiferous series and represented by small and infrequent outcrops protruding through the sand plain to the south of the hill are the crystalline limestones of the Grenville series. As elsewhere through the region, the nepheline bearing rocks are intermediate in position between the crystalline limestones and the granite-gneiss batholith. The following types have been selected as the more important representatives of this igneous complex, although it must be understood that no sharp line exists in nature between these several varieties.

1. *Craigmontite.*—This is a very nepheline-rich syenite containing corundum. The rock is prevailingly pinkish in colour, owing to incipient alteration of the nepheline, and is rather coarse in grain. Under the microscope it is seen to be composed of nepheline, oligoclase, muscovite, biotite, calcite, magnetite and corundum. The corundum (as also in raglanite) occurs in well defined crystals, often with characteristic, barrel-shaped outline and so disposed in the rock that their longer axes are often at right angles to the foliation. Smaller individuals viewed with the microscope are often irregular shaped, owing to magmatic corrosion, usually surrounded by a corona or mantle of muscovite. An analysis of the rock is given on p. 96. The "mode," or actual mineralogical composition, as calculated from this analysis, is as follows:—

Nepheline	63·18
Oligoclase	29·66
Muscovite	4·39
Calcite	1·42
Corundum	·50
Biotite	·50
Magnetite	·10

2. *Congressite.* —This rock represents the product of differentiation in which nepheline is most abundant. It is allied to monmouthite and urtite but is richer in alkalies belonging to the 9th. order of the persalanes in the quantitative classification. The rock appears as great exposures in that part of the Craigmont hill known as Congress Bluff. It is rather coarse in grain and usually possesses a more or less well marked foliation, as in the case of the other members of the series. It is pale pink in colour owing to the large amount of nepheline which it contains this mineral having a pink colour and a distinct oily lustre. In places, however, the rock displays little white bends or streaks of albite. Sodalite when present occurs enclosed in the nepheline in the form of small grains which are bright blue in colour, while the other constituents occur as little flakes or grains, distributed through the rock serving to mark the foliation. The mica in some cases displays a tendency to segregate into little bunches.

An analysis of the rock is given on page 96.

The following is the "mode" or actual mineralogical composition of the rock as calculated from the analysis:—

Nepheline	72·48
Orthoclase	4·14
Albite	3·67
Sodalite	2·22
Muscovite	6·55
Biotite	3·36
Apatite	·34
Magnetite	3·71
Ilmenite	·46
Pyrite	·36
Calcite	1·80
Water	·71
	99·80

No orthoclase could be found in either Craigmontite or Raglanite when separations were made by Thoulet solution. No separation has as yet been made of the constituents of Congressite to confirm the presence of the small percentage of orthoclase indicated by analysis.

A portion of the CaO and CO_2 calculated as calcite is present as cancrinite which is occasionally seen in thin sections in small amount. In calculating the "mode" the nepheline is assumed to have the same chemical composition as it possesses it in the Bancroft district, viz., to contain rather more than 5 per cent of K_2O.

3. *Raglanite* is a white or grey corundiferous nepheline syenite poor in nepheline. The specimen analyzed was chosen as representative of the more highly feldspathic variety of the nepheline syenite of Craigmont. Since that time quarrying operations have exposed still more highly feldspathic phases, which may be referred to as plumasite, a name originally proposed by Dr. Andrew C. Lawson (Bull. Dept. Geol. of California, Vol. III, No. 8, pp. 219-229). An analysis of raglanite is given on p. 95. The rock is composed of about 69 per cent of oligoclase, 12 per cent of nepheline and 4·45 per cent of corundum, with subordinate amounts of muscovite, biotite, magnetite, calcite and apatite.

4. *Plumasite* is an alkali-syenite made up almost exclusively of white oligoclase with a relatively subordinate amount of corundum. Muscovite, biotite and scapolite are sometimes present as accessory constituents. Plumasite is closely allied to dungannonite.*

5. *Umptekite* is the red or pink alkali-syenite and differs from plumasite chiefly by reason of the fact that a considerable quantity of potash feldspar is present. Usually it is distinctly foliated, the structure being marked by minute scales of biotite. An analysis of the rock is given on p. 96. Umptekite is, perhaps, the most abundant representative of this alkali series at Craigmont. Its approximate mineralogical composition is of orthoclase and microcline (30 per cent), albite (55 per cent), magnetite with a little biotite and corundum. Some specimens contain small amounts of hornblende or pyroxene as accessory constituents replacing the biotite.

6. *Anorthosite* has only recently been recognized in some of the newer workings at Craigmont. It is a coarsely granular rock of greyish or greenish-grey colour. It is composed, essentially, and sometimes almost wholly, of a plagioclase feldspar, having a composition intermediate be-

*It is to be noted that the feldspar in Lawson's plumasite is highly altered, containing 1.7 per cent of water. It has the specific gravity and extinction angles of oligoclase but the composition of andesine.

tween oligoclase and andesine. Most of the exposures however, contain a variable quantity of deep pink garnet, magnetite and corundum. Under the microscope the thin sections show the presence of subordinate amounts of muscovite, biotite, scapolite and a deep green spinel.

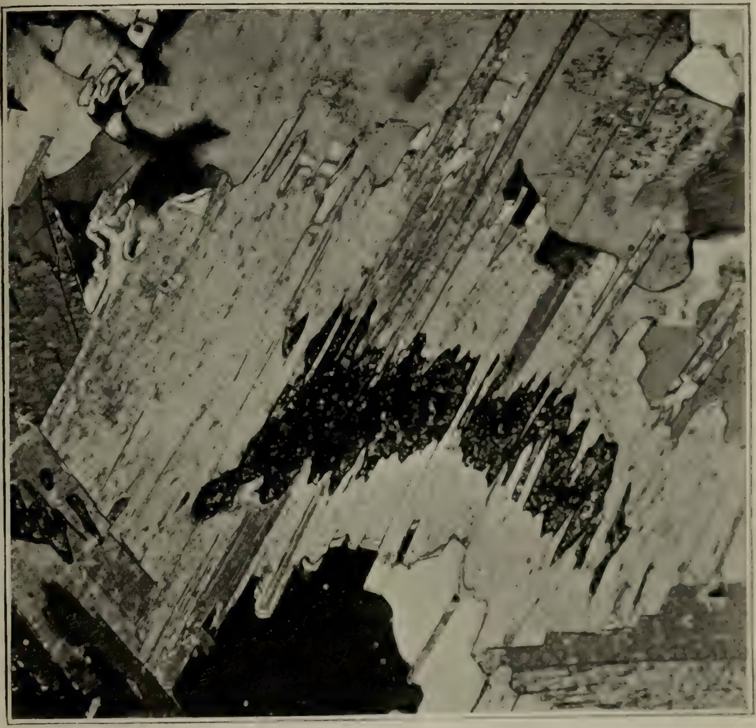
7. *Scapolite rock.*—Some of the quarries show the presence of a pale greenish granular rock made up almost exclusively of scapolite. This mineral has a specific gravity of 2·67, showing that it is of intermediate composition in the scapolite series. Associated with this scapolite are small bands of magnetite.

8. *Amphibolite* occurs intimately associated with the other members of the corundiferous series chiefly as dark greenish bands, analogous to similar inclusions in the granite gneiss batholiths. Some bands are highly micaceous, while others are composed almost altogether of hornblende. In some cases they are apparently highly deformed and altered basic dykes.

9. *Corundum syenite pegmatite* is the rock which contains the largest and most abundant crystals and masses of corundum at Craigmont and thus is the richest 'ore" which has been quarried or mined. This rock occurs in the form of dykes, which sometimes attain a width of eighteen feet. Sometimes these dykes cut across the banding or foliation of the series, but usually run parallel with these structures. There is often a distinct and perfect gradation between this coarse-grained phase and the normal type of syenite (No. 4), which also contains corundum, although in less abundance and in smaller individuals. The rock is made up almost entirely of a deep, flesh-red to very pale salmon pink feldspar, which in thin section under the microscope is seen to be an irregular intergrowth of orthoclase and albite, the latter, as indicated by the analysis, being the more abundant. Associated with this microperthite as accessory constituents, locally and usually in small amount, are biotite, muscovite, scapolite, calcite, magnetite, hematite (micaceous iron ore), molybdenite, pyrite, pyrrhotite, chalcopyrite, chrysoberyl, spinel and quartz. Although quartz and corundum are commonly supposed to be mutually exclusive, specimens have been found containing these two minerals in small amount.

This syenite pegmatite is representative of the final stages in the crystallization of this highly aluminous magma.

Mr. M. F. Connor has made an analysis of this corundum-syenite-pegmatite from Craigmont, Ont., the results adjusted to a basis of 100 being given under I. For purposes of comparison the analysis of the corundum-syenite-pegmatite, and of the corundum-syenite from



Corundum enclosed in muscovite "red syenite". Just west of Blue Mountain, Methuen, Ont. X 56 diam. Bet. crossed nicols.

Nikolskaja Ssopka in the Urals, Russia, are included under II and III. (Tschermak's Min. und Pet. Mittheil., XVIII, 1898, p. 219). Under I (a) is given the analysis of I, omitting the corundum and adjusting it to a basis of 100. Under II (a) and III (a) are similarly included analyses of II and III, in which the corundum is neglected

and the remaining constituents recalculated to a basis of 100. Under IV is an analysis of the separated microperthite from the corundum-syenite-pegmatite of Craigmont, Ont. Under V is an analysis of a similar feldspar of the corundum-syenite-pegmatite from Sivamalai, India, [**7**, p. 202].

—	I	II	III	Ia.	IIa.	IIIa.	IV	V
Corundum	34·62	35·40	18·55	......	......	......	......	......
SiO_2	40·53	40·06	52·34	62·30	62·71	64·65	63·43	63·26
Al_2O_3	13·62	13·65	16·05	20·93	21·37	19·83	20·78	21·87
Fe_2O_3	0·19	0·35	0·45	0·29	0·55	0·56	0·29	0·22
FeO	0·04	......	......	0·06	......	......	......	......
CaO	0·67	0·30	0·20	1·02	0·47	0·25	1·00	0·21
MgO	......	0·15	0·16	....	0·23	0·19	0·07	......
K_2O	5·92	5·20	6·58	9·10	8·14	8·14	8·00	3·09
Na_2O	3·40	3·71	4·77	5·23	5·81	5·89	5·20	10·25
H_2O	1·01	0·46	0·40	1·07	0·72	0·49	1·00	0·78
	100·00	99·28	99·50	100·00	100·00	100·00	99·79	99·68

The frequent occurrence of corundum in the nepheline syenites of Ontario gives these rocks a unique petrographical position, for although similar rocks occur as differentiation products of the corundum syenites of India or Russia, no corundum has yet been found in these countries in varieties which actually contain nepheline.

There is no doubt whatsoever that the corundum in these rocks is a true pyrogenetic mineral being clearly a primary constituent which separated out of the highly aluminous silicate magma as one of the first products of its crystallization.

The amount of corundum present in certain varieties of these syenites is sometimes very large, thus the ordinary red syenite-pegmatite of Craigmont was found to contain 34·14 per cent of corundum; while dungannonite from the Township of Dungannon contains 13·46 per cent of this mineral. As a result of the crushing and concentration conducted on a large scale for a period of two years at the Craigmont mill, it was found that 10·6 per cent of corundum was separated from the rock treated, while a small portion of the mineral still remained in the tailings.

Miles and Kilometers.

Combermere. Returning to Combermere the journey will be continued by steamer up Madawaska river, across Kamaniskeg lake and up Barry's bay (an arm of Kamaniskeg lake) to the wharf at the north end. The exposures on either side of the lake are principally of Laurentian granite gneiss, with the usual amphibolite inclusions. In a few places there are small isolated patches of the Grenville series.

461·37 m.
742·5 km. **Barry's Bay**. Alt. 988 ft. (301·1 m.)—is a station on the Parry Sound branch of the Grand Trunk railway. From this place the railway runs through a heavily drifted country. Any exposures seen are of the prevailing granite gneiss with amphibolite inclusions.

476·3 m.
766·5 km. **Killaloe**. Alt. 601 ft. (183 m.)—Outliers of flat-lying Palaeozoic rocks are first met with to the west of Killaloe, and from this point eastward the character of the country rapidly changes, the rugged Laurentian region being succeeded by the comparatively flat or slightly rolling district underlaid by rocks of Palaeozoic age.

Golden Lake:
Douglas. —From the vicinity of Golden Lake to Douglas the railway follows the valley of Bonnechère river, underlain by flat-lying Ordovician strata. Near Glasgow and Arnprior, as well as between Carp and South March, are extended outliers of Pre-Cambrian limestones and gneisses.

570·50 m.
918·1 km. **Ottawa.** Alt. 212 ft. (64·6 m.).

662·25 m.
1065·8km. **Vaudreuil.** Alt. 85 ft. (25·9 m.).

686·70 m.
1115·1 km. **Montreal.** Alt. 47 ft. (14·3 m.).

TABLE OF ANALYSES OF NEPHELINE AND ALKALI SYENITES FROM CENTRAL ONTARIO.

	Syenite, (Phlegrose). Monmouth, Con. VIII, Lot 15.	Nepheline syenite. (Essexose) Monmouth, Con. IX, Lot 16.	Nepheline syenite. Essexose) Monmouth, Con. VIII, Lot 11.	Nepheline syenite. (Vulturose) Monmouth, Con. VIII, Lot 11.	Monmouthite. Monmouthose) Monmouth, Con. VIII, Lot 10.	Alkali syenite. (Miaskose) Methuen, Con. X, Lot 13-14.	Alkali syenite, (Kalerudose) Methuen, Con. X, Lot 13-14.	Craigmontite with Corundum (Craigmontose) Raglan, Craigmont.	Raglanite, with Corundum. (Raglanose). Raglan, Craigmont.	Dungannonite with Corundum (Dungannonose) Dungannon, Con. XV, Lot 12.	Alkali syenite with Corundum. (Umptekose) Raglan, Craigmont.	Syenite pegmatite with Corundum. Raglan, Craigmont.	Congressite. Craigmont.	Nepheline syenite, (Lujavrose). Glamorgan, Con. III, Lot 32.
SiO_2	64·15	51·58	43·67	42·72	39·74	59·68	65·89	48·38	55·45	49·56	56·05	40·53	41·58	44·00
TiO_2	......	·35	·78	·38	·13	none	none	Trace	·30	......	·47	....	·22	·75
Al_2O_3	19·04	19·40	20·91	25·08	30·59	23·48	19·73	30·54	21·65*	33·70	17·02	13.62 (°°)	30·36	23·31
Fe_2O_3	1·02	4·26	3·54	2·00	·44	·59	2·03	·40	·81	·93	9·10	·19	2·46	2·37
FeO	·93	5·25	8·01	4·36	2·19	·37	T ·75	·06	·49	1·42	4·20	·04	1·64	7·43
MnO	·16	·20	·05	·16	·03	none	race	Trace°	·01	......	·08	....	·03	·22
CaO	1·37	3·64	7·37	6·92	5·75	·26	·46	1·87	3·65	5·89	·72	·67	·88	4·86
MgO	·37	·49	1·46	·97	·60	·21	·27	·19	·13	·97	·12	....	·37	·25
K_2O	7·10	4·23	2·25	2·69	3·88	4·68	3·95	3·70	1·62	1·23	5·12	5·92	5·15	3·09
Na_2O	5·37	7·49	6·73	11·02	13·25	9·52	6·59	13·94	9·31	4·95	6·10	3·40	14·30	10·65
P_2O_5	·10	·15	·11	·19	(A)	none	none	Trace	·01	......	·04	....	·07	·33
CO_2	·70	1·53	2·37	2·99	2·17	·04	·44	·62	·88	·17	......	1·01	·80	·98
H_2O	·27	1·02	2·52	·88	1·00	·66	·34	·50	1·64	·84	·36	....	1·01	1·45
	100·38	99·59	99·77	100·36	99·86 (x)	99·49	100·45	100·20 (x)	100·40 (x)	99·66 (x)	99·38	100·00	99·55† (x)	100·06 ‡

(A) SO_3 trace, Cl ·02, S.07. (x) New type. (°) Cu trace. *There must be added 4·45 per cent of corundum which was determined separately. (°°)There must be added 34·62 per cent of corundum which was determined separately. †With ·02 per cent of BaO, a trace of S_2O, ·30 of Cl, and ·36 of FeS_2. ‡With trace of BaO, ·01 of SO_2, ·08 of Cl, and ·28 of FeS_2.

REFERENCES.

1. Adams and Barlow. Geol. Surv. Can., Geology of the Haliburton and Bancroft Areas. Memoir No. 6, Pub. No. 1082, 1910.

2. Adams, F. D....... "On the Geology of a Portion of the Laurentan Area lying to the North of the Island of Montreal": Ann. Rep., Geol. Surv. Can., N. S., Vol. VIII, Part J, 1896.

3. Cross, Iddings, Pirsson and Washington.... Quantitative Classification of Igneous Rocks: Univ. of Chicago Press, 1903.

4. Daly, R. A. .... "The Mechanics of Igneous Intrusion": Am. Jour. Sci., Ser. 4: Vol. XV, 1903.

5. Report of the Special International Committee on the Nomenclature of the Pre-Cambrian Rocks of the Lake Superior Region: Jour. Geol., Vol. XIII, 1905.

6. Report on the Special Committee on the Correlation of the Pre-Cambrian rocks of the Adirondack Mountains, the "Original Laurentian Area" of Canada and Eastern Ontario: Jour. Geol. Vol. XV, 1907.

7. Holland, T. H...... Mem. Geol. Surv. Ind., Vol. XXX, Part 3, 1901.

8. Lawson, A. C...... Bull. Dept. Geol. of Calif., Vol. III, No. 8.

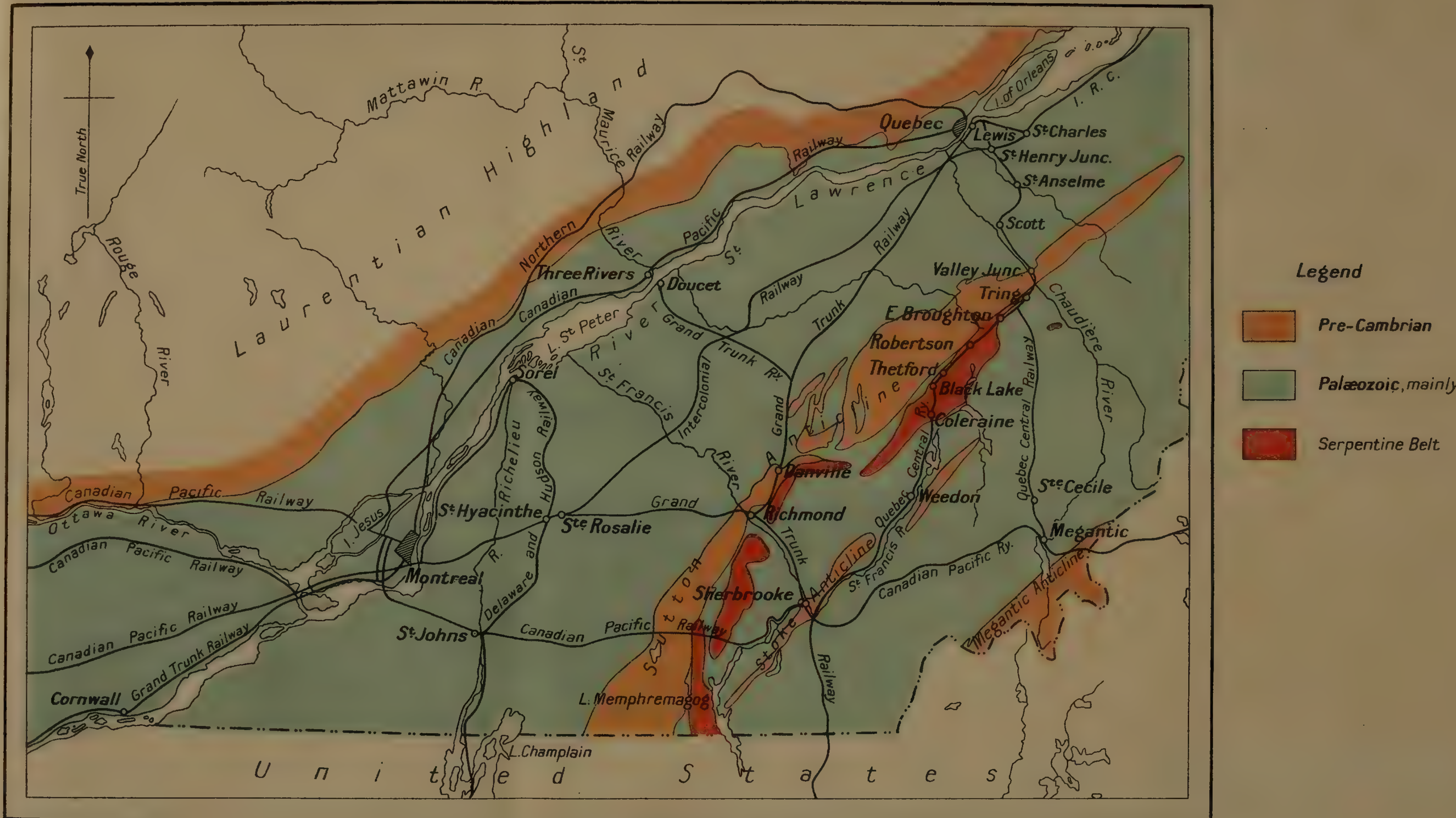
9. Morozewicz, J. . . . . . Tscher. Mitt. Band XVIII, 1908.

10. Sauer. A.. . . . . Das alte Grundgebirge Deutschlands, etc., Comptes Rendu, de IXeme Congrès Géol. Internat. (Vienna) 1903, and other papers.

11. Smyth, C. H. . . . . Report on the Crystalline Rocks of St. Lawrence County, N.Y. State Museum, 49th Ann. Rep., 1895, Vol. II.

12. Stansfield, A . . . . "Tool steel direct from the ore in an electric furnace": Jour. Can. Min. Inst., Vol. XIII, 1910.

13. Washington, H. S. . . "Chemical Analyses of Igneous Rocks": U. S. G. S., Prof. Paper, No. 14, 1903.



Geological Survey, Canada.

Figure I. The Asbestos District of Quebec

Miles
25 0 25 50 75 100

Kilometres
25 0 25 50 75 100 125 150

EXCURSION A 5.

Asbestos Deposits of the Province of Quebec.

BY

ROBERT HARVIE.

CONTENTS.

INTRODUCTION.

The purpose of this excursion will be to examine the character and mode of occurrence of the asbestos and chromite deposits of Quebec, and to observe the methods of mining. At Thetford and Black Lake the asbestos occurs in an igneous intrusion of stock-like proportions, while at East Broughton it occurs in a sheet or sill. The most typical deposits of chromite will be examined at Black Lake.

The district yields over three quarters of the world's supply of asbestos, with an annual value, at present, of about $3,000,000.

The first geological work in the asbestos district was carried on under Sir William Logan prior to the discovery of the more important bodies of asbestos bearing rocks. Sir William drew attention to the economic possibilities of these rocks, and gives a large amount of general information about them in his "Geology of Canada, 1863."

Subsequent reports of the Geological Survey of Canada added to this information, the next important advance being the reports by R. W. Ells in 1886 and 1888, which give the results of more detailed mapping after the development of active mining. In 1903 a Bulletin on Asbestos was published.

A monograph by Fritz Cirkel was issued by the Mines Branch in 1905, which describes the occurrence, uses, and methods of mining and concentrating asbestos. Chromite was also treated in a similar manner in a further report by Cirkel in 1909. Both these volumes deal more especially with the mining side of the subject, the geology receiving relatively much less attention.

In 1907 a detailed examination of the serpentine belt in which the asbestos and chromite deposits occur was begun for the Geological Survey by J. A. Dresser. His reports of progress, appearing in the Annual Summary Reports of the Geological Survey for 1907, 1909 and 1910, give the fullest accounts of the geology of these deposits yet published. The general description of the asbestos producing area which follows is taken nearly verbatim from Dresser's Summary Report for 1909.

GENERAL DESCRIPTION OF THE ASBESTOS PRODUCING REGION.

Physical Features.—The portion of the Province of Quebec which lies south of the St. Lawrence river consists of two distinct parts: the St. Lawrence plain, and the Appalachian highlands. The St. Lawrence plain, so-called, is really a broad, flat valley, which, since its average gradient is scarcely 10 feet (3 m.) in a mile (1·6 km.) appears to be a level plain. Near the International Boundary line it extends southeast of the St. Lawrence river for a distance of 50 miles (80 km.), but grows narrower farther down the river, and terminates where the Notre Dame highlands reach the river about 100 miles (160 km.) below Quebec city. The St. Lawrence plain is part of the greater lowland which extends from the lower part of the St. Lawrence river to Georgian bay.

The highlands, which form the rest of the Province south of the St. Lawrence, are known in the Gaspé peninsula as the Shickshock mountains; while in the southern part of the Province, or Eastern Townships, they are sometimes called the Notre Dame hills. They are a northward extension of the Green and White mountains of New England, and form the most westerly member of the Appalachian mountain system in Canada.

The topography of the region is in an early stage of maturity. The altitude varies from 400 feet (122·m). to 2,000 feet (609 m.) above sea-level. The relief is characterized by numerous northeast and southwest ridges and valleys, and a smaller number of larger, transverse valleys.

The transverse valleys are those of the Chaudiere, Bécancour, Nicolet, and St. Francis rivers. These rivers all follow northwesterly courses, and are tributary to the St. Lawrence. It is not yet known whether they are older than the present hills and have cut through them as they were elevated or have been superimposed upon them by the removal of later formations, remnants of which are found in the district.

The tributary streams often run in structural valleys, and are probably younger than the main rivers. They generally have narrow valleys with steep sides, and frequently enter the main rivers by distinct falls.

These furnish the principal water-powers of the district, and have given rise to such manufacturing centres as the city of Sherbrooke, at the junction of the Magog with the St. Francis; and Windsor Mills, at the entrance of the Wattopekah to the same river.

General Geology.—Southeastern Quebec is underlain by strata of Palæozoic age, resting upon the Pre-Cambrian complex, which emerges from beneath the later rocks a short distance north of the St. Lawrence. The Palæozoic strata form an ascending series toward the southeast, except where folding and subsequent erosion have disturbed the sequence. Every geological formation from Cambrian to Devonian is represented.

The structure is far from uniform. In the northwestern part of the St. Lawrence plain, the strata are conformable from Potsdam to Hudson River. They are little disturbed in position, and dip toward the southeast at low angles, usually 5 to 6 degrees. This regularity ends abruptly at the St. Lawrence and Champlain fault, a great dislocation which extends from the foot of Lake Champlain northeasterly to Quebec city, and runs thence to the Gulf of St. Lawrence along or near the present channel of the river.

On the southeast side of this fault the strata are highly folded, and have otherwise suffered greatly from regional metamorphism. The conditions of deposition on this side were also different. The marine fossil fauna indicate cold, perhaps subarctic, conditions, and an unconformity is found at or near the base of the Ordovician, which is not found on the west side of the fault.

Over considerable areas east of the fault, the folded rocks have been planed down by erosion, so that they now underlie the eastern part of the St. Lawrence plain without expressing their structure in the topography. The sediments of the region consist of shales, limestones, and sandstones, with schists, slates and quartzites on the east side of the great fault.

The Highlands, or Notre Dame hills, consist of three parallel, anticlinal ridges running in a northeasterly direction, with two broad, intervening basins, each of which has a width of about 25 miles (40 km.). The ridges are usually distinguished as the Sutton, Sherbrooke or Stoke, and Lake Megantic anticlines. The last forms a part of

the boundary line between the Province of Quebec and the State of New Hampshire. The first mentioned is the most westerly of the Appalachian folds in this region, while the second forms the Capelton hills and Stoke mountain, and the hills of Weedon farther to the north.

The ridges contain a considerable development of ancient volcanic rocks, porphyry, and greenstones. These are overlain by sediments, some of which are probably of Pre-Cambrian age.

Closely bordering the southeast side of the Sutton ridge, is a series of basic intrusive rocks. These rocks constitute the serpentine belt, and contain the deposits of asbestos and chrome iron ore. They extend from the Vermont boundary line, with little interruption, northeasterly to the vicinity of Chaudiere river. Representatives of this series of rocks appear at frequent intervals in the eastern part of North America, from Georgia to Newfoundland. In Quebec, they consist of peridotite and serpentine, pyroxenite, gabbro, diabase, porphyrite, hornblende granite, and aplite, all of which are regarded as differentiates from a single magma. They form hills 1,500 feet (457 m.) in elevation, which in some parts cover 10 to 20 square miles in area. Other exposures are only a few hundred feet in width. The maximum width of any of these areas rarely exceeds 5 miles (8 km.) and is usually less than 1 mile (1·6 km.). In structure they are considered to form batholiths, or laccoliths, and intrusive sheets or sills.

Asbestos occurs in serpentine of two varieties which are thought to be of different ages. They may be conveniently called the Thetford and the Broughton types, and the rocks associated with them, the Thetford and the Broughton series, from townships in which they are well shown.

In the area to be described the rocks of the serpentine belt cut no rocks later than Sillery (Upper Cambrian), though they probably alter Ordovician strata. To the south of this district, however, in the county of Brome, they cut strata of Ordovician age. It is not yet proven that the rocks of the series were all intruded at or nearly at the same time. Two periods of intrusion have however been thus far determined, and others may yet be found. Hence the age of the series as a whole can only be determined approximately.

TABLE OF FORMATIONS.

1. Quaternary	Sands and gravels, stratified clay, boulder clay.
2. Ordovician-Farnham	Black slates, conglomerate.
3. Cambrian-Sillery	Red and green slates and sandstones.
L'Islet	Quartzose, grey schists and quartzite.
4. Pre-Cambrian ?	Porphyries and greenstones.
Intrusives—Post-Sillery; in part, at least, later than Ordovician—Thetford series	Peridotite, altering to serpentine, pyroxenite, gabbro, diabase, porphyrite, granite and aplite.
Post-L'Islet—Broughton series	Serpentine, soapstone, greenstone schists.

THETFORD SERIES.

The rocks of the Thetford series make up the greater part of the serpentine belt. In this district they extend southwesterly from Broughton mountain, in the township of Broughton, through Thetford, Coleraine, Ireland, Wolfestown, and Garthby townships to Big Ham mountain. After an interval of 4 miles (6·4 km.) they reappear in Little Ham mountain, and continue in a southwesterly direction to Danville, and thence to the St. Francis river. Diabase covers the largest area of any rock of the series, peridotite and serpentine the next. Gabbro and pyroxenite also form considerable masses, while granite and aplite are of relatively small extent.

Peridotite and Serpentine.—Serpentine forms the country rock of all the mines, and, with less altered peridotite, makes up many of the larger hills in the mining district. The hills near Little Lake St. Francis, near Black lake, in the southern part of Ireland, and between Belmina

and Chrysotile, as well as smaller areas in other parts of the serpentine belt, are composed of serpentine and peridotite.

Pyroxenite.—When pure, pyroxenite consists of the mineral pyroxene. There is usually present, however, more or less olivine or feldspar, the former if the rock is approaching the composition of peridotite, the latter if it tends toward gabbro.

The pyroxenite near the Danville asbestos mines is singularly coarse-textured, and much of it is composed of large pyroxene crystals, some of which measure 2 inches or more on single faces. In general, the pyroxenite is somewhat altered to soapstone.

Gabbro.—Granitoid rock types in which feldspar is present as well as pyroxene are classed as gabbro. The distinguishing feature of this rock is its coarse texture as exhibited in angular grains of grey feldspar and green pyroxene. It forms a large part of the hills above Lac Coulombre and Nicolet lake, and of Little Ham mountains. It may be seen along the roadside near the southeast shore of Black lake, and in many other places near the foot of serpentine hills. The pyroxene is sometimes altered to hornblende; the rock is then more correctly called a gabbro-diorite.

Diabase.—The diabase has the same mineral composition as the gabbro, but is much finer grained, and generally has a quite different appearance. It is a fine grained, green rock sometimes showing small, grey grains of feldspar. In other cases no individual mineral can be distinguished by the unaided eye. The rock can often be readily recognized by nodules and stringers of yellowish-green epidote, a mineral that has been formed by the alteration of feldspar, and, in part, also of pyroxene. There is frequently a little quartz with the epidote.

Diabase may be well seen along the Quebec Central railway between Black Lake and Thetford; also near the Roman Catholic church at Black Lake. It forms the hills about Clapham lake, and near the Little Nicolet lakes. It carries copper and iron pyrites, in places, as at Lac Coulombre. In places, by becoming more acid in composition and losing much of its pyroxene, the diabase passes into porphyrite near the outer edges of the mass.

Granite.—The granite, though limited in extent, is important, as it probably indicates conditions that favoured the development of asbestos. It forms hills in the north-eastern part of Coleraine, dykes in most of the mines, and, in places, isolated masses grading into the enclosing diabase or porphyrite. These isolated masses are, probably, primary segregations.

Structural Relations.—The rocks of the Thetford series are obviously intrusive in their relations to the enclosing sediments. Evidences of this are: alteration of the sediments in the outer contact zone; deflection of their dip and strike; and development of contact breccias.

The alteration of the sediments is sometimes shown by a hardening of a band near the contact, producing a hornstone rim. The grey slates are often given a rusty, reddish colour, due apparently to the oxidation of sulphides developed near the contact, while the originally red Sillery slates are usually bleached to pale pink. Fragments in the breccia, and larger portions of sediments near the contact, show partial absorption by the igneous magma. Some of these rocks still preserve the lines of foliation of schists on weathered surfaces, but on freshly broken faces they cannot be distinguished from the enclosing, or adjacent, igneous rock.

Dykes are very rare, and altogether there is a very noticeable absence of evidence of any violent eruption. The intrusion seems to have progressed slowly, and without any marked cataclysmic action. The contact is thus of the batholithic order.

The bodies of igneous rock appear to take two principal forms. From Broughton mountain to Little Nicolet lake, where the igneous belt crosses the stratification somewhat obliquely, the intrusions occupy elliptical or rounded areas, bordered by breccia, and giving evidence of downward enlargement. With the exception of one district, and two doubtful intervals, they form a continuous mass, and so are interpreted as being a batholith, or very thick laccolith.

In other parts of the district, the boundaries of the intrusions conform more closely to the stratification, are generally brecciated on one side only, and occupy long narrow areas. In cross section they can sometimes be

seen to form sills or intrusive sheets, and are consequently considered to more generally take this form.

The peridotite, pyroxenite, gabbro, and diabase, form a continuous series, passing by gradual transitions from one variety to another, in the order named. In the case of larger exposures, all of these rock types can sometimes be found in a single intrusive mass. In other cases, the differentiation is sharper, and peridotite passes into diabase with only a few feet of transitional rock between. In general, peridotite, or the serpentine derived from it, and diabase, form the larger portion of a rock mass. At the outer edges, the diabase, in places, passes into hornblende porphyrite, and this occasionally into hornblende granite, or aplite.

The granite and aplite have usually, however, been intruded a little later than the more basic rocks. The edges of these acid intrusions are generally as well crystallized as the central parts, showing that they were brought in while the basic rocks were still heated. Occasionally, too, an injection of diabase has taken place somewhat later than the intrusion of the greater part of the mass. This may be seen at Louise mountain, in Garthby, and probably near Shipton Pinnacle, but such occurrences are not common.

The rocks of this igneous complex are generally distributed in one or other of two different modes of arrangement, according to the form, of the igneous intrusion. They are arranged in order of decreasing basicity and density:—

(1) In sheets, from the base upwards.

(2) In batholithic intrusions, from the centre outwards.

Serpentine, or diabase may sometimes be much in excess of the other rocks, and thus give an asymmetric arrangement. But the more acid rocks, wherever present, are, as far as known, invariably near the tops of sheets or the margins of batholithic intrusions, and the basic rocks in correspondingly opposite directions.

In the case of sheets, the arrangement of the rocks accords with the relative densities of the principal minerals of which they are composed, and also with the order of their crystallization.

In the case of batholithic intrusions, the differentiation from basic to acid extremes, from the centre outwards,

is in agreement with well known cases of magmatic segregation in intrusive rocks, where differentiation has taken place prior to intrusion.

The batholithic intrusions near Thetford characteristically consist of a dome-shaped central mass of peridotite, bordered, or sometimes nearly surrounded, by an erosion valley. The outer side of the central mass is formed by a ridge of diabase, or porphyrite, which again passes into breccia at its outer edge.

It may be mentioned that an identical relation of rock types has also been found in association with the platinum bearing peridotites of the Ural mountains.

BROUGHTON SERIES.

The Broughton series consist of serpentine, soapstone, and greenstone schists. They are the rocks containing, and adjacent to, the asbestos and talc deposits of Robertson, East Broughton, and Broughton, and of several isolated locations in the vicinity.

The greater alteration of these rocks indicates that they are possibly earlier in age than the Thetford series, although this difference may also be due to a greater degree of metamorphism. The sediments enclosing them are the grey schists and quartzites, in no case the red slates of the Sillery formation. It can, therefore, only be said of their relations that, they are intrusive in, and hence later than the L'Islet formation which conformably underlies the Sillery.

ECONOMIC GEOLOGY.

The minerals of economic value that have been found in the serpentine belt are asbestos, chrome iron ore, talc, antimony, copper, and platinum. Of these, asbestos alone is at present being mined, the production of which represents one-half of the total mineral production of the Province of Quebec, and is upwards of 80 per cent of the world's output of asbestos. Chromite has at times been produced in considerable quantity, but the industry has never passed the prospecting stage and at present operations have ceased altogether. Antimony and talc have

been mined; there has been a small development of the copper ore; and platinum has been found in the gravels.

The discovery of asbestos as a mineral of commercial importance was made in this district in 1877, although it was known for many years previously as a mineral of prospective value. Mining operations began at Thetford, Black Lake, and very shortly afterwards at Danville, and have continued ever since. Since the introduction of a successful method of mechanical concentration, about 1893–4, the production has increased regularly, until it now has an annual value of about $3,000,000. Notwithstanding this steady and increasing production, no well-established mine has yet been worked out. Aside from the abandoned pits incidental to early prospecting, the only closed works are those of ill-judged enterprises that probably ought never to have been begun.

The production for the past ten years has been as follows:—

Year.	Tons.	Value.
1902	30,634	$1,161,970
1903	29,261	916,970
1904	35,479	1,186,795
1905	48,960	1,476,450
1906	62,375	2,143,653
1907	61,985	2,455,919
1908	65,156	2,551,596
1909	63,349	2,284,587
1910	100,430	3,403,358
1911	100,893	2,922,062

Various attempts to mine chrome iron ore in Quebec were made between 1860 and 1890, but it was not until 1894 that any considerable production was made. Between 1894 and 1908 over 40,000 tons of chromite were mined, which had a value at the railway of about $600,000. Since 1908 the industry has declined, till at present none of the deposits are being worked. The development of new ore bodies has not kept pace with the exhaustion of those being worked.

The following production during the last four yeras of active work was as follows:—

Year.	Tons.	Value.
1905	8,528	$104,585
1906	8,750	92,100
1907	7,196	72,901
1908	7,225	82,008

BLACK LAKE.

At Black Lake the chief points of interest are: the rock types of the peridotite series; occurrence and relation of asbestos veins; mining and milling of the asbestos-bearing rock; occurrence, mining and milling of chromite ore.

Rock Types of the Peridotite Series.

Of the rock types of the peridotite series, diabase, porphyrite, peridotite, serpentine and granite are present at Black Lake.

The diabase and porphyrite occur as marginal phases of the peridotite stock at the contact with the sediment, in a few localities the contact being marked by a breccia in which fragments of the sediments are cemented by a paste of the diabase. In general both these rocks have been so much altered that it is only by careful microscopic work that they can be distinguished. Both are now commonly represented by a fine grained chloritic or epidotic rock. In some places typical pillow structure may be observed; at others, the rock has the appearance of a tuff or breccia.

It is difficult, and often impossible to distinguish peridotite and serpentine in hand specimens. In the field and in mining operations, they are collectively called serpentine. The peridotite is composed of olivine, a small amount of pyroxene, and a little chromite and magnetite. The serpentine is merely an altered phase of the peridotite. The mineral serpentine is derived from olivine by hydration accompanied by loss of the iron content. Pyroxene may also alter to serpentine; but it changes less readily than olivine, having originally more silica in its composition, and more frequently it alters to soapstone or talc. The olivine is sometimes completely altered to serpentine, in which case the pyroxene crystals when

any are present show as glistening grains, usually $\frac{1}{8}$ inch or less in diameter. On weathered surfaces they stand out in relief, giving a rough surface to the serpentine, like raised nail heads, or knots in a worn floor. This is well shown in the rock near the summits of the serpentine and peridotite hills above Black Lake village.

The granite in this area is composed of feldspar, quartz and hornblende or biotite, or both. It is light grey in color, and occasionally shows a pinkish tint. Types without hornblende or mica,—principally dykes, are also present, but are more properly classed as aplite. The granite is considered to be the end product of the process of differentiation and nearly contemporaneous with the peridotite. The peridotite retained at least sufficient heat at the time of the intrusion of the granite dykes to enable them to cool without a fine grained border.

Occurrence and Relations of Asbestos Veins.

The asbestos is of the chrysotile variety—hydrous silicate of magnesium—and has the same chemical composition as the serpentine which contains it, but is distiguished from it by a fibrous form. The asbestos occurs almost wholly in veins which are usually 2½ inches or less in width, the greater number being less that ½ inch. The fibres lie usually at right angles to the walls of the veins, hence the length of the fibre is limited by the width of the vein; but it rarely equals it, for there is usually a parting in the vein which is marked by a film of iron ore, generally magnetite. The veins are invariably bordered by a band of pure serpentine on either side of the vein, whether the country rock is wholly or partially serpentinized, or even a slightly altered peridotite. These serpentine bands bordering the veins are usually as well defined as the vein itself, and in width are proportionate to it, each being nearly three times the width of the asbestos vein.

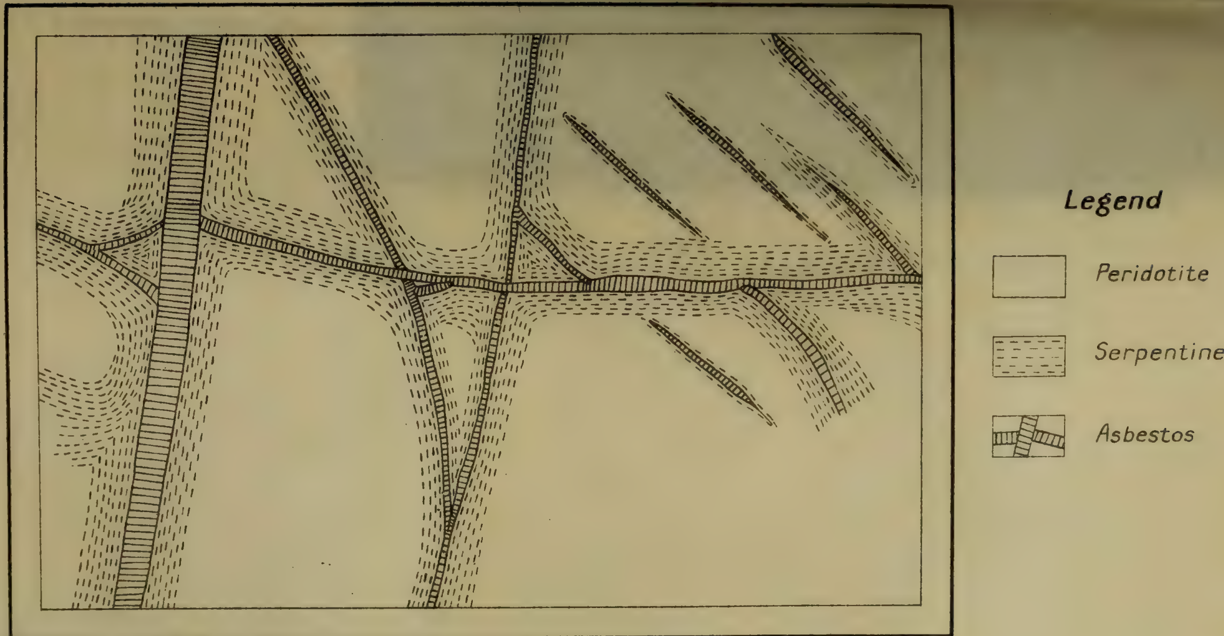
From a consideration of these facts, and of the number, size, and directions of the veins, it is believed that they were formed, not by the filling of once open fissures, but by the replacement or crystallization—more or less perfect —of the pure amorphous serpentine of the side walls. This process is thought to have begun at a fracture, now indicated by the parting or film of iron ore within the vein.

and to have extended into the wall rock on one or both sides to a distance proportionate to the width of the serpentine bands. They thus belong to the class of veins sometimes called exogenous or outward growing, as

Photomicrograph of an asbestos vein, showing the irregular nature of the magnetite parting, and the contact of the vein with the serpentine wall-rock. X 14; crossed nicols.

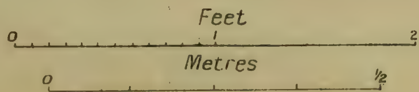
distinguished from those that are formed by filling a fissure from the walls inward. Measurements of many veins show that the proportion of asbestos to the two bands of serpentine is 1 to 6·6, or that approximately 15 per cent of the serpentine has taken the crystalline form of asbestos.

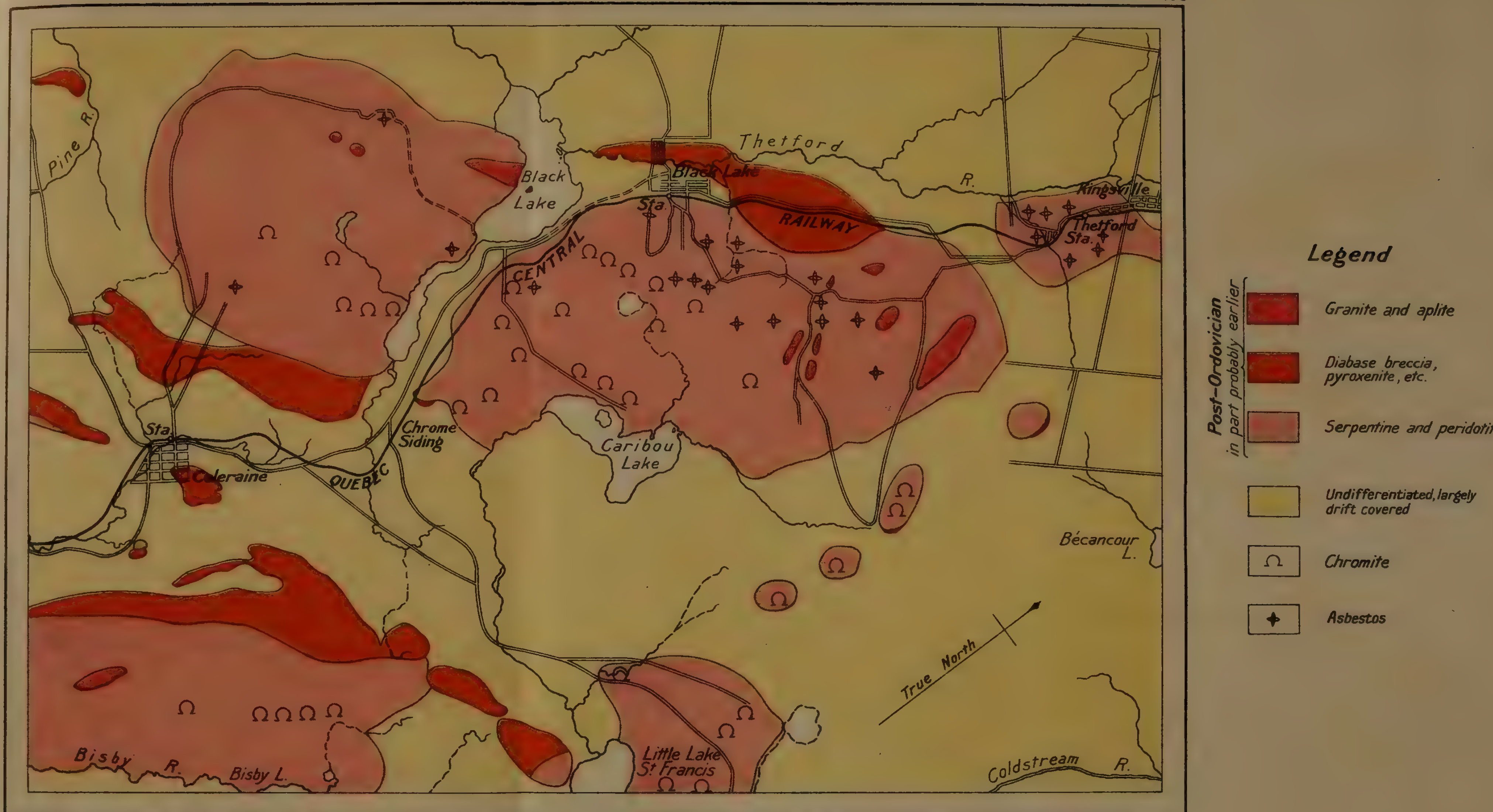
In the Thetford or later serpentine, many of the larger veins can be seen to follow joint planes in the original rocks. Another class seems to have grown from fractures caused by regional folding, as is indicated by their approximate parallelism. Fractures, produced in early stages of disintegration of the rock by casting off shells from the jointed blocks, give a series of crescent-shaped veins,



Geological Survey, Canada.

Figure 2, *Asbestos and serpentine in peridotite, wall of pit near Standard Mine.*





Geological Survey, Canada.

Route map between **Thetford** and **Coleraine**

Miles

Kilometres

surrounding a core of peridotite. Where all of these classes of veins are found together, a very intricate network results, but by careful observation many of them can be referred to one or other of these clasess.

The determination of other causes of the shattering of the rock, such as hydration, rapid cooling, and, possibly, original gneissic structure near the edge of an intrusion, requires a full investigation covering the entire process of serpentinization.

Mining and Milling of the Asbestos-Bearing Rock.

All the mines are worked by open-cut methods. The ground at the bottom of the pit is usually cut into a series of benches, generally about 8 to 15 feet (2·4 to 4·5 m.) high, which afford a number of faces from which the rock can be quarried at the same time. At the Bell mine, Thetford, extensive underground work has been carried on in winter with apparent success. Generally, the mines are operated only by day. Several of the pits have reached a depth of about 200 ft. (61 m.), with two or three times greater horizontal extension.

In some of the mines the asbestos-bearing portion is separated from the barren rock in the pit, and in part, the "crude" from the mill stuff. A certain amount of hand cobbing is also done in some pits. In most, however, all hand separation is done at the surface. There, the separate products are emptied into tramcars, drawn usually by small locamotive engines; the dead rock is then taken to the waste dump, and the rock which will afford crude asbestos, to the cobbing sheds, where it is separated by hand work and put in bags. The remainder, usually 35 to 60 per cent of all the rock handled, goes to the ore bins, or directly to the mill for mechanical concentration.

Except for minor differences in handling, the principles used in the treatment of the asbestos-bearing rock are the same at all the mills. The dried rock is crushed by stages. The crushing is effected by means of gyratory or jaw crushers, or both, followed by rolls, and then cyclones or jumbos, the particular style of machine employed being largely a matter of the personal taste of the manager. Between each stage of crushing, the material is passed

over screens, close above which are the inlets of suction fans by which any fibre is removed. The undersize passes on to the next screens while the oversize is ground further. Partial grading of the asbestos is effected by this removal of the fibre at the various stages in the crushing process, and this grading may be further improved by screening. Magnets are usually employed over the shaking screens to eliminate particles of iron ore.

The milled fibre is separated into three or more grades, and the crude asbestos usually into two.

Chromite.

The most important chromite deposits are reached from Black Lake village, but as they all present similar characteristics, the Montreal pit is described as a typical example.

Mode of Occurrence.—The Montreal pit is in a serpentinized peridotite near a contact with diabase,—the latter rock occurring in the opposite slope of the little valley. The ore body consists chiefly of a series of lens-shaped bodies of massive chromite. Associated with this is a large quantity of ore consisting of disseminated grains of chromite in the serpentine country rock, sufficiently rich to concentrate.

The whole deposit has been faulted and squeezed to such a degree as to produce an infinite number of slickensided surfaces. For this reason the ore is deceiving, as it tends to break along the film of serpentine in these slickensides so that what may appear to be merely a block of serpentine is in reality massive ore. Cutting the serpentine are several kaolinized granitic dykes, numerous blocks from which are to be found on the dump and some of which contain an unusual pink vesuvianite.

Mining and Milling.—The ore was mined by means of open cuts, and by a drift from the bottom of the main or lower pit. At least 2,200 tons of crude and 500 tons of concentrated ore have been shipped from these workings.

In the method of concentration used, the ore, after preliminary breaking in a jaw crusher, was fed to three batteries of five stamps each. The pulp from each battery

passed over a Wilfly table, which gave three products, concentrates, middlings, and tails. The middlings from all three tables were treated on a fourth table which produced concentrates and tails. The concentrates after draining were ready for shipment.

The ore was graded, and sold according as the content of chromic oxide was greater or less than 50 per cent. The highest percentage reached was very rarely above 55, and with some ores difficulty was experienced in obtaining even 50 per cent. This last trouble was evidently due to the

Photomicrograph of chromite ore showing intergrowth of two varieties,—black, opague iron and chromium-rich variety, showing black; and brown, translucent, magnesian variety, showing mottled. The white streaks are glare from films of inclosed serpentine. X 55.

chromite having an undue amount of Cr_2O_3 replaced by Al_2O_3, so much so that the per centage of Cr_2O_3 remained low even with a very complete removal of the gangue.

Thin sections of some of the ore show it to be composed of an opaque black variety, high in Cr_2O_3, and a reddish, translucent variety containing less Cr_2O_3.

THETFORD.

The visit to Thetford affords further opportunities for the study of the occurrence, mining, and milling of asbestos —subjects which have already been discussed for the occurrence at Black Lake.

EAST BROUGHTON.

The interest at East Broughton centres in the rock types, and, the occurrence of asbestos in sills.

Rock Types.

The rock differs from that of Thetford and Black Lake, in being much softer and more shattered. It is almost completely serpentinized, the only exception being certain hard blocks which carry no asbestos. The asbestos recovered here rarely occurs in veins, but generally as slip or parallel fibre, being, in fact, only the softer and partially fibrous, outer portions of the individual pieces into which the rock is shattered. A microscopic examination of these rocks is still necessary in order to determine the actual mineral composition of these hard blocks, and to find out, if possible, whether the asbestos-bearing portion was originally similar to that in the Thetford series. The presence of considerable bodies of talc, and steatite or soapstone, indicates that there was a good deal of pyroxene in the original rock. There is very little chromite in the serpentine of this class.

The altered greenstones are chloritic and epidotic schists, probably originally diabase, together with hornblende schists which grade into them. The latter may be the altered, more acid parts of the primary rock, perhaps corresponding to the porphyrite of the Thetford series. The precise character of these rocks can only be determined by detailed lithological examination, which has not yet been made.

The appearance of the rock is at first disappointing as there are no signs of the cross fibre veins which are so much in evidence at Thetford. However, on crushing the rock to a fine powder a considerable amount of short fibre is found. The asbestos produced at East Broughton is all of short fibre and of low grade, no crude whatever being

obtained. The fibre appears to lie chiefly along the slipping planes, which are the result of the shattering of the rock into innumerable small pieces by some such cause as swelling during serpentinization, general regional metamorphism, or folding. The rock is much more completely altered than that of the Thetford deposits and now consists almost entirely of serpentine with a certain amount of talc —the latter indicating the impure nature of the original peridotite.

SILLS.

In striking contrast to the deposits at Thetford and Black Lake, which are in the margin of a stock several miles across, the asbestos deposits at East Broughton occur in sill-like bodies. Two pits have been opened to the full width of a sill about 100 feet (30 m.) thick of which both the foot and hanging walls are exposed. Other smaller parallel sills also occur close at hand. The main sill extends nearly continuously for 6 miles (9·6 km.), five pits having been opened up in this distance. It is also probable that the pits of the Berlin, B. & A., and the Robertson Asbestos Co., 8 miles (12·8 km.) farther on, are in the same sill, so that the sill has a probable length of about 14 miles (22·5 km.).

BIBLIOGRAPHY.

1. Logan, Sir William . . .Geol. Surv. Can.
Geol. of Canada, 1863.
2. Adams, F. D. . . . . . . .Geol. Surv. Can.
Rept. of Progress 1880–1–2.
3. Ellis, R. W . . . . .Geol. Surv. Can.
Vol. II. Part J., 1886.
4. . . . . .Geol. Surv. Can.
Vol. III., Part K., 1887–8.
5. . . . . .Geol. Surv. Can.
Vol. IV., Part K., 1888–9.
6. Cirkel, Fritz. . . . . .Chrysotile-Asbestos. Dept. of Mines. Mines Branch, Pub. No. 11. 1905.
7. . . . . .Chromite. Dept. of Mines. Mines Branch, Pub. No, 29. 1909.
8. Dresser, J. A. . . . . .Geol. Surv. Can.
Summary Repts. 1907–09–10.

EXCURSION A 9.

Mineral Deposits near Kingston, Ontario.

BY

M. B. Baker.

CONTENTS.

GENERAL DESCRIPTION OF THE REGION.

The district about Kingston occupies a unique position mineralogically in that it affords a great variety and abundance of well developed minerals, many of which are present in such amounts as to be of economic value. A partial list of these follows:—

Actinolite,	Graphite,
Amphibole,	Hematite,
Anhydrite,	Ilmenite,
Anorthite,	Labradorite,
Anthraxolite,	Milky quartz,
Apatite,	Molybdenite,
Arsenopyrite,	Muscovite,
Barite,	Nepheline,
Beryl,	Plagioclase,
Biotite,	Pyrite,
Bog iron,	Pyroxene,
Bytownite,	Pyrrhotite,
Calcite,	Rutile,
Celestite,	Scapolite,
Chalcopyrite,	Sphene,
Corundum,	Talc,
Dolomite,	Uralite
Fluorite,	Wilsonite,
Galena,	Zinc-blende,
Garnet,	Zircon,
Gold,	

More than half of these minerals have been mined in this area so that they are not mere accessories requiring microscopic detection.

This area is particularly interesting, also, in showing the contact of the Paleozoic sediments with the Pre-Cambrian floor. The former lie unconformably upon the latter, and at several places the actual contact is excellently shown. Here the ancient Pre-Cambrian water-worn boulders are cemented into a basal conglomerate of the lower Paleozoic sediments; such exposures give an excellent demonstration of the character of Pre-Cambrian topography, and show clearly that the great "Laurentian Peneplain" was developed in Pre-Cambrian times,—an eloquent evidence of the enormous time which elapsed between the

close of the Pre-Cambrian and the opening of the Paleozoic era.

The Pre-Cambrian portion of this district presents an undulating but not greatly elevated topography. The average elevation is about 500 feet (152m) above sea-level. There are so few exceptions to this, that the whole country presents an almost level sky-line, with few if any projections rising notably above the rest. The area is dotted with lakes, occupying from one-third to one-half of the whole area; only a few of these have been mapped, but the result is striking in bringing out their north-easterly elongation. This is governed by the strike of the gneisses of which the area is largely composed, and not by glaciation as might be suggested. This north-east and south-west system of drainage is characteristic of the whole "Laurentian Peneplain," as a glance at the map of Eastern Canada will show.

The Pre-Cambrian area under consideration on this excursion consists of the typical Laurentian, together with the Grenville phase of the Keewatin. The recent work of Adams [**1**], Barlow [**2**], Miller and Knight [**3**] would indicate that the Grenville is made up largely of highly metamorphosed sediments, and this probably accounts for the great variety of well-individualized minerals developed throughout this area. The whole Pre-Cambrian complex is so intensely metamorphosed and infolded, that with the exception of the crystalline limestones, it is not easy to distinguish the Grenville from the Laurentian metamorphic rocks.

The whole district consists essentially of gneisses. In some localities their foliated character is so faint that they might be called granites. These gneisses differ very markedly among themselves in the proportion of their constituents. The typical rock consists of quartz, orthoclase, and biotite, but in many places hornblende takes the place of the biotite; or the quartz becomes so abundant that the rock might be mistaken for a quartzite; or the feldspar so predominates, that the rock passes into a syenite gneiss. Seldom over any great area do the rocks maintain the same composition, and the minerals enter into their composition in every conceivable proportion.

It is probably safe to conclude that the distinctly lightly coloured, grayish to reddish psamitic gneisses, rich in hornblende, belong to the Laurentian, as in the case of

the Lewisian gneisses of the North-west Highlands of Scotland. On the other hand the lustrous pelitic gneisses rich in mica, or other hydro-micaceous minerals probably belong to the Grenville group as in the case of the Highland schists of Scotland, or the Telemark formation of Norway. In many gneisses there is a distinct ribbon-like, or banded character, in which parallel bands of different composition, often quite thick, extend for long distances along the strike. The writer would suggest that this is due to an original difference in the material caused by the sorting action of water or other agency.

Both of these gneisses are cut in numerous places by granite dykes, many of which are pegmatitic. It is from these great pegmatitic dykes that the potash feldspars are mined in large quantities for use as glazes for earthenware. These dykes occur in great numbers, and two of the productive ones are included in the excursion programme. There is little doubt that most of the interesting minerals, so well developed in this area, are due in large measure to the metamorphism produced by these intrusives, or to solutions and gasses which accompanied them.

These occurences have been excellently exposed by the glaciation of Pleistocene times. This was sufficient to remove all the weathered material from both hill and hollow, so that the old contour of the Pre-Cambrian is preserved, while its surface is made quite fresh again for detailed study. There has not been sufficient time since glaciation for any appreciable weathering, so that all the occurrences are now seen at their best. The effects of the glaciation are in themselves interesting. The famous Glacial Gardens of Lucerne, Switzerland, scarcely surpass the examples of glaciation to be seen immediately about Kingston.

The Paleozoic portion of the area is an irregular fringe along the south-west flank of the Pre-Cambrian. The number of outliers of sediment scattered over the Pre-Cambrian suggests that they at one time completely covered it in this portion of the Dominion, but have been removed by denudation. These lie almost horizontally, dipping only 6 to 9 degrees to the south-west. They are for the most part, clean limestones running as high as 96 per cent calcium carbonate. They are shaly in a few places, but, as a rule, very compact, affording an excellent building stone. A reddish sandstone is found as the lowest member of the series, and is tentatively correlated with the Pots-

dam (Upper Cambrian), the evidence being purely stratigraphic, for no fossils are found in this formation. These sandstones are rather noted, however, for the purely concretionery forms they contain. To the south-west of the sandstone and at a higher horizon, are the Lowville limestones (Lower Ordovician).

As a surface covering for the whole district is the usual glacial drift of Pleistocene times. This drift is quite unsorted in most places over this area, but in a few localities has been water-sorted into great beds of clay, sand, gravel or boulders. The clays are used for the manufacture of common brick and tile; the sand and gravel for building purposes, road-metal or railway ballast; and the boulders in some cases for building rubble masonry. Most of the drift is unsorted however, so that splendid sections of glacial drift, with its variety of boulders, and its erratics can be obtained.

LEAD, PHOSPHATE AND MICA DEPOSITS.

INTRODUCTION.

This excursion has been planned to visit a few of the economic deposits found in the Pre-Cambrian rocks of this district. Some of these, for example the mica deposits, are amongst the largest producers in the world, and are therefore interesting. Others, like the phosphate mines, were formerly large producers, but are no longer worked. Their association is so much like that of the phosphate deposits of Norway, as described by Broegger and Reusch, that they should prove interesting. The lead property is not a big producer, but the occurrence is interesting in that it illustrates a point in ore deposition, for where the wall rocks are gneiss the ore is galena with no zinc blende, but where they are crystalline limestone both galena and zinc blende occur. This excursion will also afford an excellent opportunity for studying the general character and topography of a typically Pre-Cambrian area.

Miles and Kilometres.

0 m. 0 km. **Kingston.** Going in a northerly direction from Kingston for the first thirteen miles, the road runs over the flat-lying Ordovician sediments, whose general characters have already been described.

13 m. 20·8 km. **Loughboro Lake.** 18 m. 22·8 km. **Perth Road.** At Loughboro Lake it passes on to the Pre-Cambrian area, and continues for 5 miles to Perth Road, where a fissure vein of white calcite carrying galena and zinc blende is being mined. This deposit was located in the early seventies, and was worked in a desultory fashion until 1875. It was then leased to an English company, which from a shaft 250 feet (76·1 m.) deep mined about 2,000 tons of ore averaging 12 per cent lead, and 5 ounces of silver to the ton of galena.

Following the strike of the vein northwestward it passes into a swamp, but emerges again after half a mile, at which point it contains both zinc and lead. Moreover the wall rocks have changed from gneiss on the south side of the swamp, to crystalline limestone on the north side, the contact lying somewhere in the swampy ground.

In 1880 a lead smelter was built in Kingston to treat these ores, but after two years of operation the property and smelter were abandoned and remained so until two years ago, when the present company took them up. This company has rebuilt the smelter and is treating domestic ores, lead refuse, as well as the concentrates from their own mines at Perth Road. They have traced the vein farther northwestward and are developing the property more thoroughly than was ever done before.

Miles and Kilometres.

Five miles (8 km.) in a southwesterly direction, is the abandoned

23 m. 36·8 km. **Foxton Mine.** Foxton phosphate mine. This was opened in 1878 by James Foxton, and from it calicum phosph ate was mined for the manufacture of fertilizers. This mineral is found in segregations within pyroxenite intrusions which cut the Grenville gneisses and crystalline limestones. The mineral varies in colour from sea-green, through reddish, pink, greyish, to brown, and is usually in large crystalline masses, but occasionally in finer granular masses or "sugar-phosphates". The pyroxenite intrusives cut the Grenville gneisses and crystalline limestones, and are therefore clearly of later age. The pyroxenite itself is cut by dykes of more acidic character ranging from diabase to pegmatite. The close association of many of the largest deposits of apatite with these later dykes would suggest that the development of the phosphate in the pyroxenite was partly due to these later intrusions. The phosphate does not occur as true veins or fissure fillings, but rather as segregations or pockets in the basic pyroxenite intrusives. Where these latter conform to the gneissoid structure of the country rocks, a banded appearance, suggestive of vein structure, would naturally be produced. This occurrence is extremely like that of the phosphate deposits of Norway, which are described by Broegger and Reusch as occurring in basic gabbro.

After a careful study of all the phosphate deposits in Canada, Mr. E. D. Ingall says "The phosphate bodies are distributed through these belts in the most irregular manner. In a few instances they show a general extension of the phosphate in a plane, which gives them the appearance of having followed a vein, but there are no walls, nor sharp planes of division which persist for any distance between the phosphate and the enclosing rock. Most of the excavations

made show the bodies of mineral to be of extremely irregular shape, merging into the enclosing rock, and holding varying proportions of inter-mixed rock. At places very large bodies of almost pure phosphate have been encountered, yielding many thousands of tons."

The phosphate of this district is usually closely associated with mica and pink calcite, and in the early days of the mining industry, the mica was removed and went to the dump as a waste product—many hundreds of tons in this way being lost to commerce. In actual mining it was frequently found that the phosphate was of little economic value when it occurred with calcite and mica, for the amount was insufficient to repay the actual cost of its separation by itself. The great economic deposits of the mineral were those in which the apatite was found in large pockets without much mica being present. It would therefore appear that certain deposits within the pyroxenite are composed essentially of apatite, mica, and pyroxene; while others are essentially calcite, mica, and pyroxene. Naturally there will be deposits of intermediate character where calcite, apatite, mica, and pyroxene will be intimately associated. It is also clear that many of the phosphate mines later became mica mines, especially as the phosphate industry in Canada was soon displaced by that of the Southern States.

The phosphate in this district carried 80 per cent or more of calcium phosphate. This was shipped to the town of Smith's Falls, on the Rideau Canal, and was there manufactured into fertilizers. The mineral was ground by buhr-stones to 100 mesh, then conveyed to a vat with sulphuric acid, where it was agitated for twenty-four hours. Hydrofluoric acid was liberated, and allowed to pass off into the air, while in the vat a precipitate of calcium sulphate was formed, and calcium acid phosphate went into solution thus:—

Miles and Kilomteres.

$$Ca_3(PO_4)_2 + 2H_2SO_4 = 2CaSO_4 + CaH_4(PO_4)_2.$$

After drying, the whole mass was disintegrated and mixed with proportions of hydrochloric acid, ammonium sulphate, potassium and sodium nitrates, and sold in various grades of fertilizer from $32 to $44 per ton.

Many accessory minerals are to be found about the old dumps of this property, including phlogopite, scapolite, wilsonite, pyroxene, pyrite, zircon, calcite, hornblende, and many others.

28 m.
44·8 km.

Lacey Mica Mine.

A mica deposit of the type mentioned in discussing the phosphates, lies in a southerly direction from the Foxton mine. Segregations in such cases as the Foxton mine often contain calcite, mica, and pyroxene, and form splendid sources of mica. The best deposit of this kind yet discovered, and one of the biggest individual mica mines in the world, is the Lacey mine, which is now the property of the General Electric Company of Schenectady, New York. This mine was first opened as a phosphate mine when the market was active for that substance in 1879. It was never profitable as a phosphate mine, however, and was converted into a mica mine and worked spasmodically from 1880 to 1901 by local individuals, or small companies. It was then taken over and operated by the present company, who obtain a product from it surpassing in quality and quantity anything that had been anticipated. The property has been opened to a depth of 185 feet (33·4 m.), and pockets have been found 25 feet (7·6 m.) in width, which were almost a solid mass of mica crystals. These were of enormous sizes; the largest one is said to have been over 9 feet (2·7 m.) in diameter.

The mica of this mine is exceptionally well suited to electrical purposes. Being light

Miles and Kilometres.

amber in colour, it is transparent, so that defects, flaws, or inclusions can be easily seen. It is quite pliable and can be bent into various shapes without cracking. Its chief use is in insulating the parts of electrical machines, and, being incombustible and resistant to decomposition, it is unimpaired by time. Lacking sufficient quantity of large-sized mica to satisfy the demand, the users have now succeeded in building up plates of required sizes from small pieces cemented together with shellac. The resulting product, called "micanite," has practically all the qualities of the larger pieces of clear mica. The mica used for this purpose is not poor scrap mica, but simply the smaller sizes of the high-grade mica. The still smaller, waste sizes are padded to make boiler covering, or finely ground to a mica flour, which may be used for tempering steel, or as an absorbent for nitro-glycerine in the manufacture of an explosive called "mica powder," or as a lubricant for wooden bearings, or, mixed with oil, for metal bearings.

39 m.
62·4 km.

Counter's Corners.

Returning 11 miles (17·6 km.) towards Kingston, a visit is made to a barite vein, which cuts the flat-lying Ordovician limestone. At Counter's Corners this vein is from one (3 m.) to four feet (1·2 m.) wide. It dips vertically, and strikes northwest, and can be picked up at intervals as far as Varty lake, a distance of 14 miles (22·4 km.). The limestone is dense and hard, with shaly partings, and its contact with the barite is very sharply defined, so that there is no transition from the one into the other. Moreover, along the contact is a coating of anthraxolite, and some fluorite, indicating that the vein had not filled from the surrounding country rocks, but owes its origin to a deep-seated source. Approximately 100 tons have been mined

A 9.

Geological Survey, Canada.

Route map between **Sydenham** *and* **Glendower**

Miles
1 0 2 4 6

Kilometres
1 0 2 4 6 8 10

la
ie
ca
A

from the east end of this vein, ground in a local flour mill, and shipped for paint manufacture.

Barite vein in Ordovician limestone.

FELDSPAR, CORUNDUM AND SCAPOLITIZATION.

INTRODUCTION.

The object of this excursion is to examine certain large pegmatite dykes, from some of which quartz and feldspar are mined in commercial quantities, a good indication of the size and perfection of their crystallization. A rather unusual occurrence of corundum will be seen in

anorthosite, and examples of scapolitization will also be seen. In a series of augite gabbros, the feldspars have changed to scapolite, while the pyroxene has changed to uralite, producing an interesting rock, good samples of which may be procured. Associated with this rock is a body of titaniferous magnetite, which was formerly mined. The route of this excursion lies entirely in Pre-Cambrian country.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m.
0 km. **Kingston.**

25 m.
40 km. **Verona.**

Travelling from Kingston over the Kingston and Pembroke railway to the village of Verona, carriages will take the party to the Richardson feldspar mines on Thirteen Island lake. Half a mile (·8 km.) from the town is an exposure of Grenville dolomite containing graphite, chondrodite, and phlogopite mica in small crystals. One and a half miles (2·4 km.) farther on is a large pegmatite dyke, in which feldspar and quartz are so largely developed that they have been mined separately and shipped for industrial purposes.

33 m.
52·8 km. **Richardson Feldspar Mine.**

Six miles (9.6 km.) farther on lies the Richardson Feldspar mine, the largest mine of its kind on the continent. This deposit is an enormous pegmatite dyke, from which the potash feldspar and the quartz are mined separately. In the process of treatment the feldspar is fused, and forms a glaze for such clay products as earthenware dishes, electrical insulators, reflectors, porcelain tubs, bath-room fixtures, and household untensils. The quartz is used in electrical furnaces at Niagara Falls for fluxes, ferrosilicon manufacture, artificial abrasives, carbide, and other manufactures. This mine has turned out as much as 30,000 tons of feldspar in one year. The

Miles and Kilometres.

excavation is now 500 feet (152·3 m.) long, 200 feet (60·9 m.) wide and 130 feet (39·6 m.) deep, all of which work has been done in the last 8 years.

Crossing Thirteen Island lake, and Thirty Island lake, and about half a mile west of the latter lake are the old pits of the Glendower Iron mine. The mine is situated at, or close to the contact of Grenville gneisses with crystalline limestone. The property was worked from about 1873 to 1890, but has since been idle, apparently on account of the increase in sulphur in the ore beyond a depth of 150 feet (45·7 m.), where iron pyrites became so abundant as to render the ore unfit for use.

35 m.
56 km.

Glendower Iron Mine.

The occurrence of interest at this point is the so called "plagioclase scapolite diorite" of Adams and Lawson, [**5**]. In the excursion to the lead, phosphate and mica deposits, it was noted that a series of pyroxenites, which cut up through the Grenville gneisses and crystalline limestones, were constantly associated with the apatite deposits. In places these intrusives appear to have been more acidic in character, becoming augite diortites which contained originally augite, hornblende, plagioclase, and some quartz. The hornblende so predominates that when foliated, they have been called amphibolites. In places they present a mottled appearance, closely resembling the "geflecter gabbro" associated with the apatite occurrence in Norway. This mottled appearance is due to concentrations of black, coarsely crystallized hornblende in a lighter colored ground mass, made up of scattered hornblende crystals in a greenish waxy looking mineral of feldspathic appearance. This lighter portion is more easily weathered than the hornblende spots and is often somewhat sunken below the general surface.

Miles and Kilometres.

An examination under the microscope shows that this greenish feldspathic mineral is scapolite secondary after plagioclase. In some places the polysynthetic twinning of the plagioclase can still be seen in the scapolite. Most of the amphibole is a rich green original hornblende, but some of it is secondary uralite after augite. This secondary hornblende is darker in color, and is more or less fibrous or shreadlike, and is intergrown with pyroxene, which often remains as "rests" with a collar or uralite surrounding. Accessory minerals in the scapolitized rock are epidote, enstatite, rutile, and pyrrhotite.

For these reasons, this rock has been termed a plagioclase scapolite diorite, and where it has been rendered more or less foliated or schistose, it is called a "plagioclase scapolite amphibolite." The scapolitized gabbro is much freer from oxide of iron than is the ordinary augite diorite or gabbro, and Dr. W. G. Miller suggests [**6**] that in the process of alteration of the gabbro, the iron oxides were leached out, and deposited from solution in the neighboring limestone, thus giving rise to the iron ore bodies.

37 m.
59·2 km.
47 m.
75·2 km.

Godfrey
Parham.

From this point a return is made over the branch railway line to Godfrey, and thence northward over the main line to Parkham. In this vicinity the railroad passes through some cuts in the same scapolitized gabbro. One of these ridges followed northwestward leads to Eagle lake, where another abandoned phosphate mine, the Boyd Smith, is seen.

Boyd Smith Phosphate Mine.

This property was second only to the Foxton mine, as a producer of phosphate, when that industry was at its height. At that time considerable titaniferous magnetite was found, and some of it was formerly mined.

The magnetite carries traces of cobalt and nickel.

Scattered about this locality are many boulders of anorthosite which carry corundum. These rocks are found "in situ" a short distance north and north-east [**7**, p. 227]. Of these boulders Dr. Miller says "They are rather dark colored on the weathered surface, but have a characteristic bluish or purplish color, which can be made out even at some distance from them, and this serves to distinguish them from the boulders of trap and other dark colored rocks, which are associated with them. The majority of the crystals of corundum have a diameter of about half an inch (1·27 cm.) and show a striking uniformity in size. The color is light grey to almost white, and they average about 5 per cent of the rock. Owing to their greater hardness and durability, they stand out well above the surface of the rock which holds them."

Under the microscope the anorthosite is seen to consist of the basic plagioclase, bytownite, with common green hornblende. Scattered through the bytownite are innumerable crystallites, which are possibly corundum although nothing was determined to confirm this suspicion."

PALEOZOIC–PRE–CAMBRIAN UNCONFORMITY.

INTRODUCTION.

Splendid opportunities for seeing the relationship of the Paleozoic sedimentary rock to the old Pre-Cambrian floor are to be had in the city of Kingston. On this excursion several points will be visited where the Paleozoic can be seen lying unconformably upon the Pre-Cambrian. In the lower basal beds, boulders of the Pre-Cambrian are cemented by a limestone mud, which gradually passes upward into clean limestone beds away from the actual contact. At one exposure of the Potsdam

(Upper Cambrian) sandstone, a group of unique concretions is to be seen. These stand in tree-like forms, in vertical position, and cross the bedding of the sandstone. One of these cylinders is fully 15 feet (4·5 m.) in diameter. These sandstones show some interesting bleaching effects, where the red iron oxides, on being leached out of the sandstone, produce white bleached spots or streaks.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. **Kingston.** Leaving Kingston by automobile, the road leads in a north-easterly direction along the west side of Rideau canal. The country is flat in character, as the rocks are bedded limestones of Ordovician age. After $4\frac{1}{2}$ miles (7·2 km.) of such country, the road descends a steep hill which forms a cliff-like margin to the old channel of Rideau river, which was incised along the contact of the Ordovician with the Pre-Cambrian floor. A half mile (·8 km.) farther on is Kingston Mills.

5 m. 8 km. **Kingston Mills.** Here the limestone is seen in the railway cutting to lie unconformably on the Pre-Cambrian. A basal conglomerate composed of large water-worn boulders of granite and gneiss cemented in a limestone mud is seen. The limestone is filled with fragments of the quartz of the old floor, this being the one imperishable mineral it contains. Within 3 feet (·9 m.) of the actual contact, the limestone becomes much cleaner, and is filled with fragments of Orthoceras and Endoceras well preserved.

The granite in the railway cutting shows perfectly fresh exposures, and some of the finest possible examples of jointing in three directions are to be seen. At the east end of the rock cut are the Kingston Mills locks on the Rideau canal, where boats are lowered

Contact of Ordovician limestone and Pre-Cambrian gneiss, Dead Man's bay Kingston.

Miles and Kilometres.

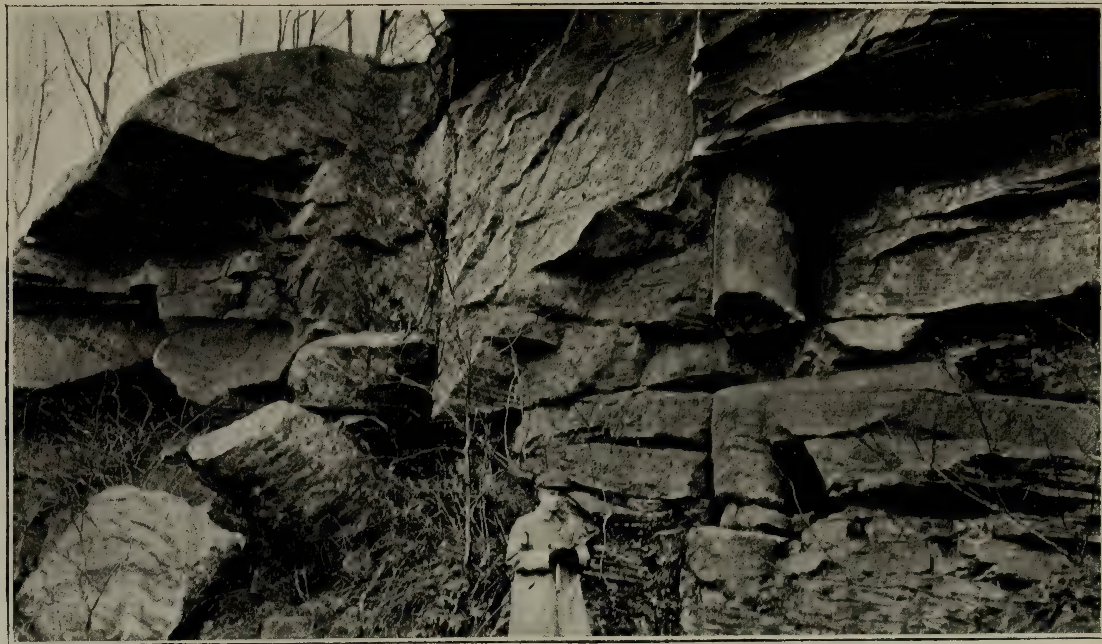
52 feet (15·6 m.) to the level of Lake Ontario. A deep gorge is cut here in the Pre-Cambrian gneisses making one of the most beautiful spots on the inland water-ways of Canada.

Resuming the journey in a north-easterly direction on the east side of the canal, for a distance of 4 miles, (6·4 km.) Blake's quarry is reached.

9 m. 14·4 km. **Blake's Quarry**.

This quarry is in Potsdam (Upper Cambrian) sandstone, and is noted for the peculiar concretions it contains. There are innumerable spherical to elliptical sandstone concretions, but the most peculiar ones are long cylindrical forms which are popularly called "Fossil tree-trunks". These stand in vertical position, and the writer would suggest that they represent structural forms laid in eddies, contemporaneously with the surrounding sands. That this sandstone was laid down in moving water is indicated by the abundance of "cross-bedding" shown here. The red Potsdam sandstone yields an excellent building stone in most parts of the quarry.

17 m. 27·2 km. **Barriefield.**—At Barriefield may be seen a "qua-qua-versal", where Pre-Cambrian gneiss forms the core with Ordovician limestones dipping away from it in all directions. A short distance farther south an intrusive granite dyke of Laurentian age is exposed. This dyke has cut through the gneisses, and along its contact a number of pneumatolitic minerals have developed, for example, fluorite, tourmaline, pyrite, as well as hornblende and chlorite. The dyke itself shows well-developed joint planes, along which these minerals have collected. Excellent glacial gouges and troughs have been preserved here, as well as glacial striation. Southward from this point on the shore of the St. Lawrence river, a classic example of basal conglomerate is exposed, where the limestones are filled with boulders of the underlying Pre-Cambrian.



Tree-like concretions in sandstone near Kingston Mills.

Miles and Kilometres.

Here the limestone is so thin that the exact character of the old Pre-Cambrian floor, before the Ordovician sediments were laid on it, can be determined with certainty. This is one of the most instructive occurrences geologically to be seen anywhere.

18 m. 28·8 km. **Kingston.**

Returning from this exposure towards Kingston some interesting weathered surfaces of limestone may be seen. This weathering has all taken place since the Pleistocene glaciation, and being so new, gives an excellent example of the progress of attack on a limestone surface.

HISTORICAL NOTE.

A few items of history, for which this particular ground is noted, might prove of interest. Fort Henry, which crowns the hill had its origin in the war of 1812. At that time these heights, and all the district eastward along the St. Lawrence river were covered with dense forest. To prevent surprise by landing parties, this forest was cut down, and a strong earthwork erected on the point. Within this, heavy guns were so mounted that they commanded the approach to the harbour, as well as to the mouth of the small bay immediately west of the present Fort; for on this ground were the ship-yards, which mark the site of the first naval yards established in this country, over a century ago. While the war was going on, this fortification, and the batteries situated on Point Frederick commanding the ship-yards, saved the town from molestations by the American fleet, whose head-quarters were less than 50 miles (80·4 km.) away. The present Fort, and the Martello towers, with their pivot guns, were built between 1840 and 1846.

The long wooden bridge, which now connects Barriefield with Kingston, has been in use for over 80 years. At the east end is the entrance to the Royal Military College, which occupies the site of the old naval yards. At the west end was the old trading post, the first one built in Canada west of Montreal. The present military barracks occupies the site of this old post. A short distance southward the City Hall is passed. This hall was built

60 years ago, as the House of Parliament of the then Province of Canada.

BIBLIOGRAPHY.

1. **Adams, F. D.**—"Recent Studies in the Grenville Series of Eastern North America." Jour. of Geol. No. VII., 1908.

2. **Adams, F. D. and Barlow, A. E.**—"Geology of Haliburton and Bancroft Areas." Geol. Sur. Can. No. 1082.

3. **Miller, W. G. and Knight, C. W.**—The "Grenville Hastings Unconformity." 16th Rep. Bur. Min. of Ont., 1907.

4. **Ingall, E. D.**—"Iron Ore Deposits along the Kingston and Pembroke Railway." Geol. Sur. Can. No. 723, 1901.

5. **Adams, F. D. and Lawson, A. C.**—"On some Canadian Rocks Containing Scapolite." Canadian Record of Science, Vol. III. No. IV., 1888.

6. **Miller, W. G.**—"Corundum and other Minerals." 8th Report of the Bureau of Mines of Ontario, p. 229, 1899.

7. **Pope, F. J.**—"Nickel in Titaniferous Magnetites.' 7th Rep. Bur. Min. of Ont., p. 230–232, 1898.

ILLUSTRATIONS.

Photographs.

PAGE.

Drawings and Sections.

Maps.

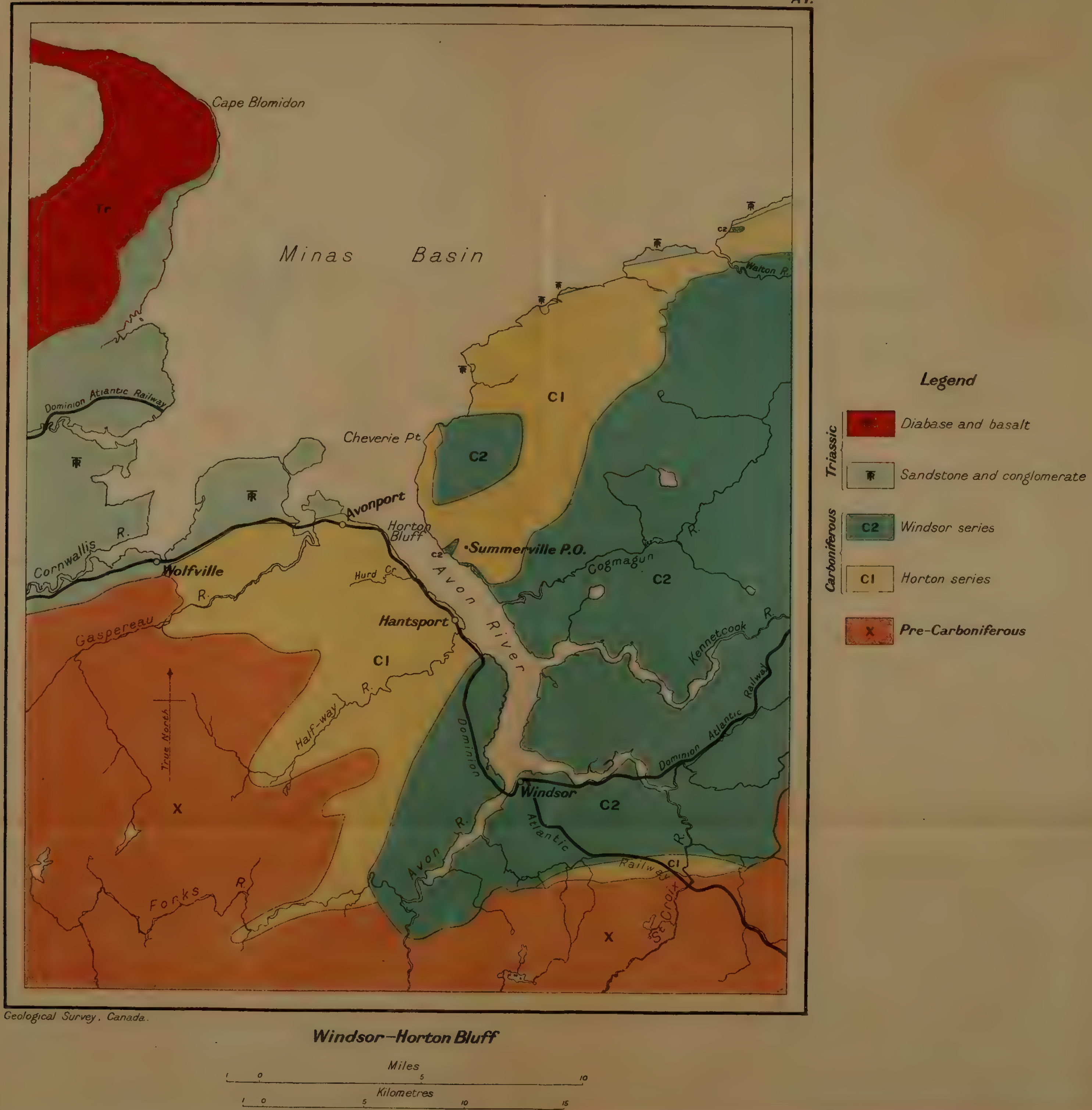
Geological Survey, Canada.

Percé and **Vicinity**

Feet: 5000 0 5000 10000

Metres: 1000 750 500 250 0 1000 2000 3000 4000

(Scale of map is approximate)



Geological Survey, Canada.

Windsor–Horton Bluff

A 1.

Geological Survey, Canada.

Bathurst Iron Mine

Geological Survey, Canada.

Sydney Coal Field

Geological Survey, Canada

Arisaig

Miles
0 1 2
Kilometres
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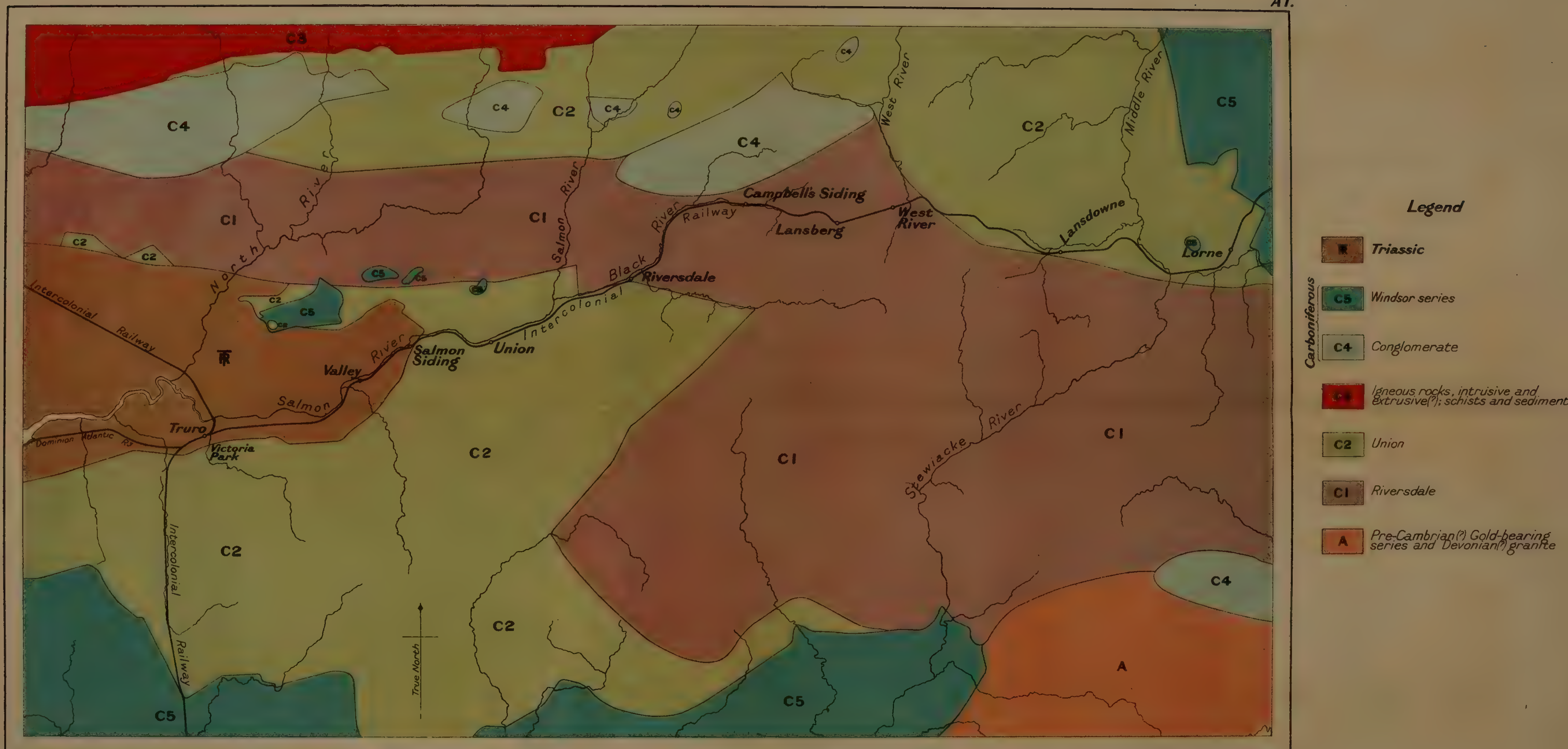
A1.



Geological Survey, Canada.

Union—Riversdale

Miles
1 0 5 10

Kilometres
1 0 5 10 15

Canada
Department of Mines
GEOLOGICAL SURVEY

HON. L. CODERRE, MINISTER. A. P. LOW, DEPUTY MINISTER
R. W. BROCK, DIRECTOR

C. O. Senécal, Geographer and Chief Draughtsman.

1277

Geographical base from engraved plates of the Department of the Interior.
Geology of Newfoundland from official map of the colony.
Geology compiled by G. A. Young.

MAP 91A
(Issued 1913)

Geological Map
of the
DOMINION OF CANADA
AND NEWFOUNDLAND

Scale, $\frac{1}{6,336,000}$

Miles

Kilometres

100 MILES TO 1 INCH